Adaptive Water Quality Monitoring and Evolving Assessments Enhance Decision-Support for Watershed and Bay Recovery in the Chesapeake Bay Program Partnership

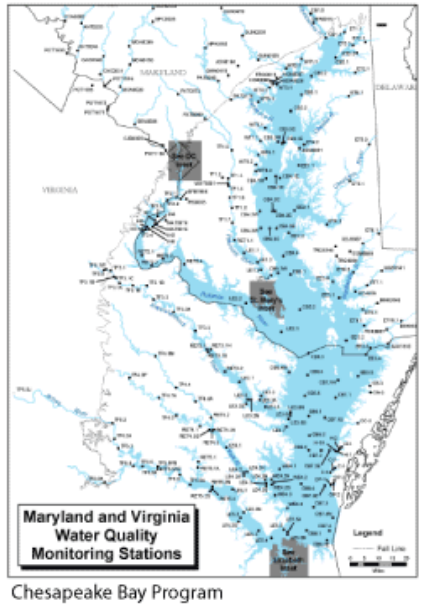
Peter Tango
USGS@CBPO
National Water Quality Monitoring Council Conference
Denver, CO
3/28/2019

USGS science for a changing world

Photo courtesy of the Chesapeake Bay Program

Chesapeake Bay Program
Science. Restoration. Partnership.

Chesapeake Bay long-term water quality monitoring program: 1984-present



Chesapeake Bay Program

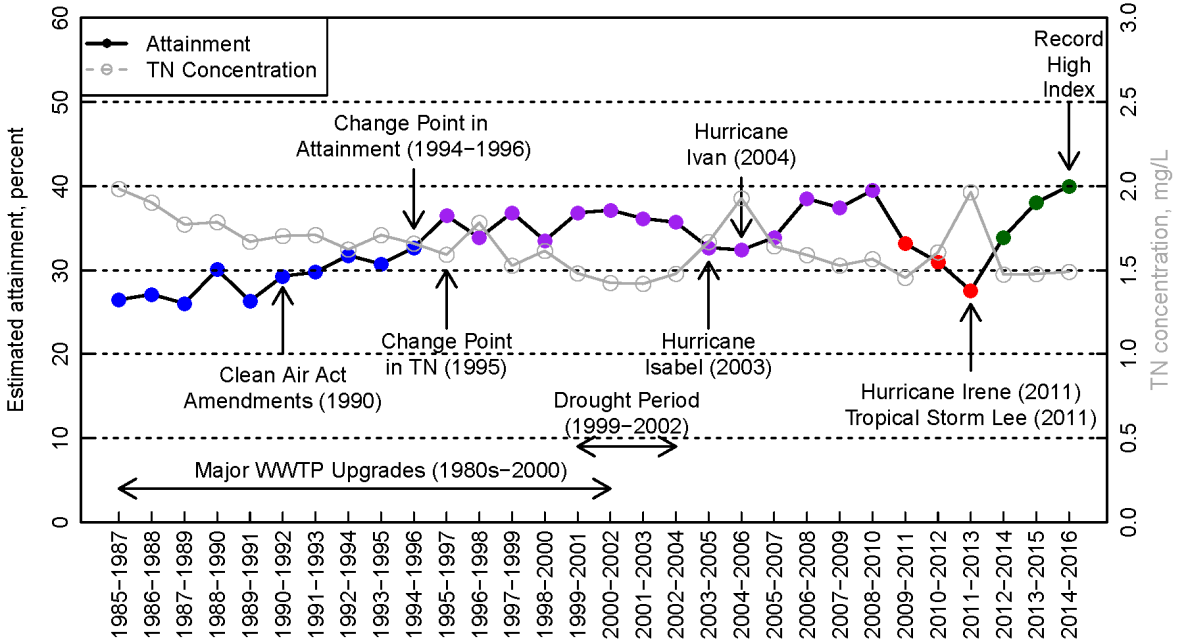
River input trends for Nitrogen, Phosphorus and Sediment

Table 1. Summary of long-term (1985-2016) and short-term (2007-2016) trends in nitrogen, phosphorus, and suspended-sediment loads for the River Input Monitoring stations.
[Improving or degrading trends classified as likelihood estimates greater than or equal to 67 percent]

Monitoring station	Total nitrogen load		Total phosphorus load		Suspended-sediment load	
	Long term	Short term	Long term	Short term	Long term	Short term
SUSQUEHANNA RIVER AT CONOWINGO, MD	Improving	Degrading	Degrading	Degrading	Degrading	No trend
POTOMAC RIVER AT WASHINGTON, DC	Improving	Improving	Improving	Degrading	Improving	No Trend
JAMES RIVER AT CARTERSVILLE, VA	Improving	Improving	Improving	No Trend	Degrading	Improving
RAPPAHANNOCK RIVER NR FREDERICKSBURG, VA	Improving	Improving	Degrading	No Trend	Degrading	No Trend
APPOMATTOX RIVER AT MATOACA, VA	No Trend	Degrading	Degrading	Degrading	No Trend	Degrading
PAMUNKEY RIVER NEAR HANOVER, VA	No trend	Degrading	Degrading	No trend	Degrading	Degrading
MATTAPONI RIVER NEAR BEULAHVILLE, VA	Improving	Degrading	No Trend	Degrading	No Trend	No Trend
PATUXENT RIVER NEAR BOWIE, MD	Improving	Improving	Improving	Improving	Improving	Degrading
CHOPTANK RIVER NEAR GREENSBORO, MD	Degrading	Degrading	Degrading	Degrading	Improving	Degrading

USGS 2018

Long term improving health trends Water Quality Standards Attainment Index



Zhang et al. 2018

What is our recovery progress?

Chesapeake Bay Program
Science. Restoration. Partnership.

Water quality outcome example: Information gap analysis points to monitoring information needs of the bay and watershed scientists, managers and policy-makers

Our capacity to Monitor

Watershed loads and trends: Adequate

Bay Water Quality Standards Attainment: Marginal

** World class monitoring programs may have gaps in their fundamental needs to obtain decision-support information.*

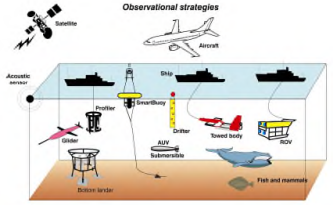
Capacity to Monitor (USEPA 2003 scale):

1. Recommended
2. Adequate
3. Marginal

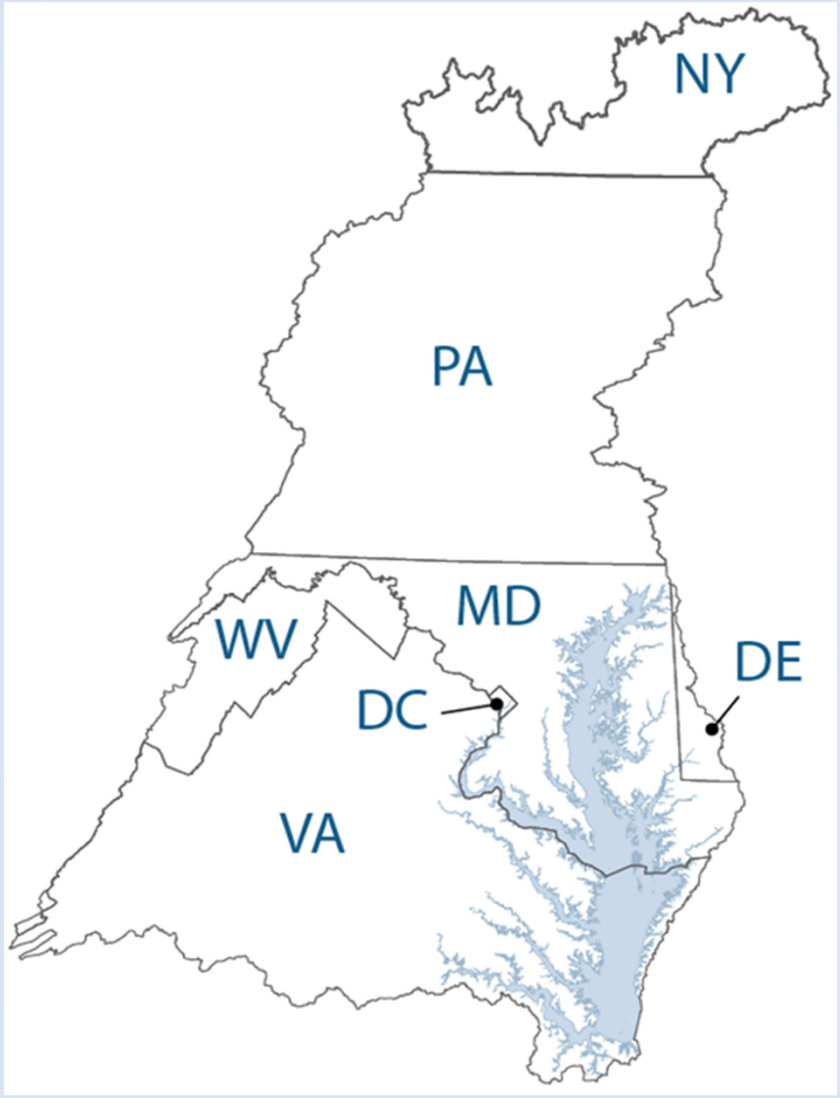
Presentation today

- Examples of 4 areas of recent adaptation and directions for enhancement to the Chesapeake Bay long-term water quality monitoring program.
  - Partnership agreement to use Citizen-derived data
  - Developing protocols for adopting satellite image interpretation into the monitoring program
  - Extended use of water quality standards attainment assessments to communicate progress
  - Improving hypoxia monitoring and assessment

CMC
Chesapeake Monitoring Cooperative



Advancements: Building new partnerships to address information gaps and data needs.

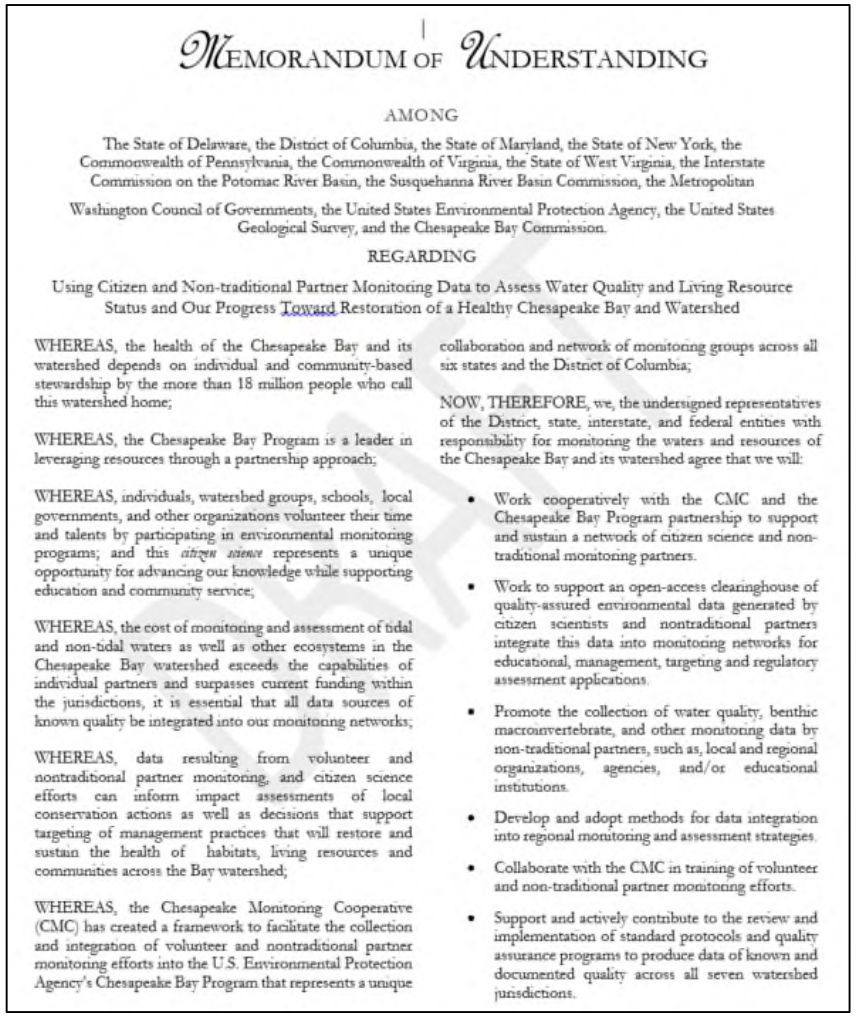


Chesapeake Bay Program

Science. Restoration. Partnership.

Advancements: Chesapeake Bay Program partnership agreement on the use of Citizen Science data.

2018 Memorandum of Understanding



MEMORANDUM OF UNDERSTANDING

AMONG

The State of Delaware, the District of Columbia, the State of Maryland, the State of New York, the Commonwealth of Pennsylvania, the Commonwealth of Virginia, the State of West Virginia, the Interstate Commission on the Potomac River Basin, the Susquehanna River Basin Commission, the Metropolitan Washington Council of Governments, the United States Environmental Protection Agency, the United States Geological Survey, and the Chesapeake Bay Commission.

REGARDING

Using Citizen and Non-traditional Partner Monitoring Data to Assess Water Quality and Living Resource Status and Our Progress Toward Restoration of a Healthy Chesapeake Bay and Watershed

WHEREAS, the health of the Chesapeake Bay and its watershed depends on individual and community-based stewardship by the more than 18 million people who call this watershed home;

WHEREAS, the Chesapeake Bay Program is a leader in leveraging resources through a partnership approach;

WHEREAS, individuals, watershed groups, schools, local governments, and other organizations volunteer their time and talents by participating in environmental monitoring programs; and this *citizen science* represents a unique opportunity for advancing our knowledge while supporting education and community service;

WHEREAS, the cost of monitoring and assessment of tidal and non-tidal waters as well as other ecosystems in the Chesapeake Bay watershed exceeds the capabilities of individual partners and surpasses current funding within the jurisdictions, it is essential that all data sources of known quality be integrated into our monitoring networks;

WHEREAS, data resulting from volunteer and nontraditional partner monitoring, and citizen science efforts can inform impact assessments of local conservation actions as well as decisions that support targeting of management practices that will restore and sustain the health of habitats, living resources and communities across the Bay watershed;

WHEREAS, the Chesapeake Monitoring Cooperative (CMC) has created a framework to facilitate the collection and integration of volunteer and nontraditional partner monitoring efforts into the U.S. Environmental Protection Agency's Chesapeake Bay Program that represents a unique collaboration and network of monitoring groups across all six states and the District of Columbia;

NOW, THEREFORE, we, the undersigned representatives of the District, state, interstate, and federal entities with responsibility for monitoring the waters and resources of the Chesapeake Bay and its watershed agree that we will:

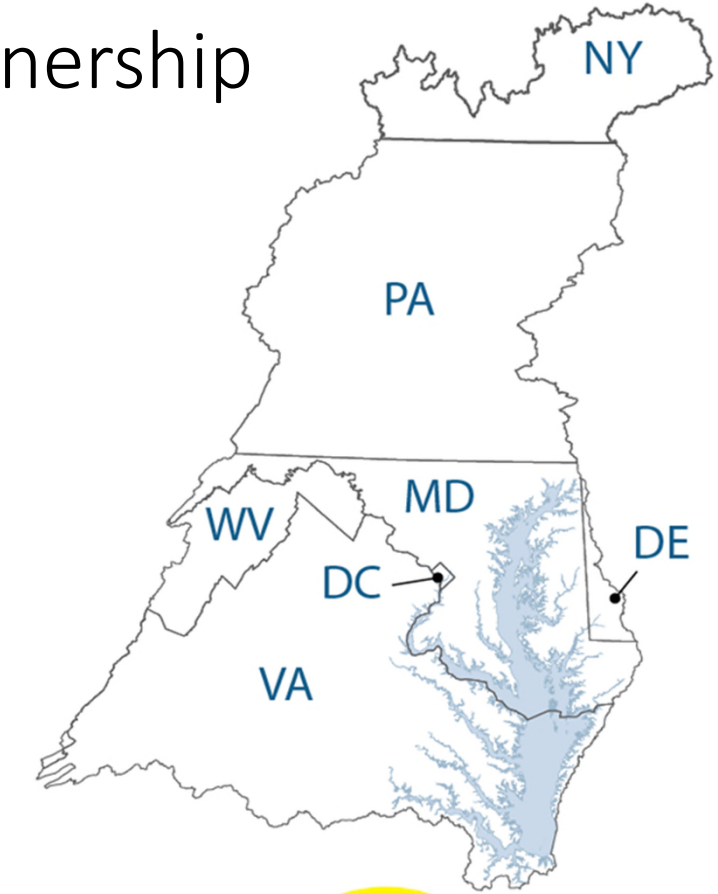
- Work cooperatively with the CMC and the Chesapeake Bay Program partnership to support and sustain a network of citizen science and non-traditional monitoring partners.
- Work to support an open-access clearinghouse of quality-assured environmental data generated by citizen scientists and nontraditional partners integrate this data into monitoring networks for educational, management, targeting and regulatory assessment applications.
- Promote the collection of water quality, benthic macroinvertebrate, and other monitoring data by non-traditional partners, such as, local and regional organizations, agencies, and/or educational institutions.
- Develop and adopt methods for data integration into regional monitoring and assessment strategies.
- Collaborate with the CMC in training of volunteer and non-traditional partner monitoring efforts.
- Support and actively contribute to the review and implementation of standard protocols and quality assurance programs to produce data of known and documented quality across all seven watershed jurisdictions.

Goal

- Use of data of known quality

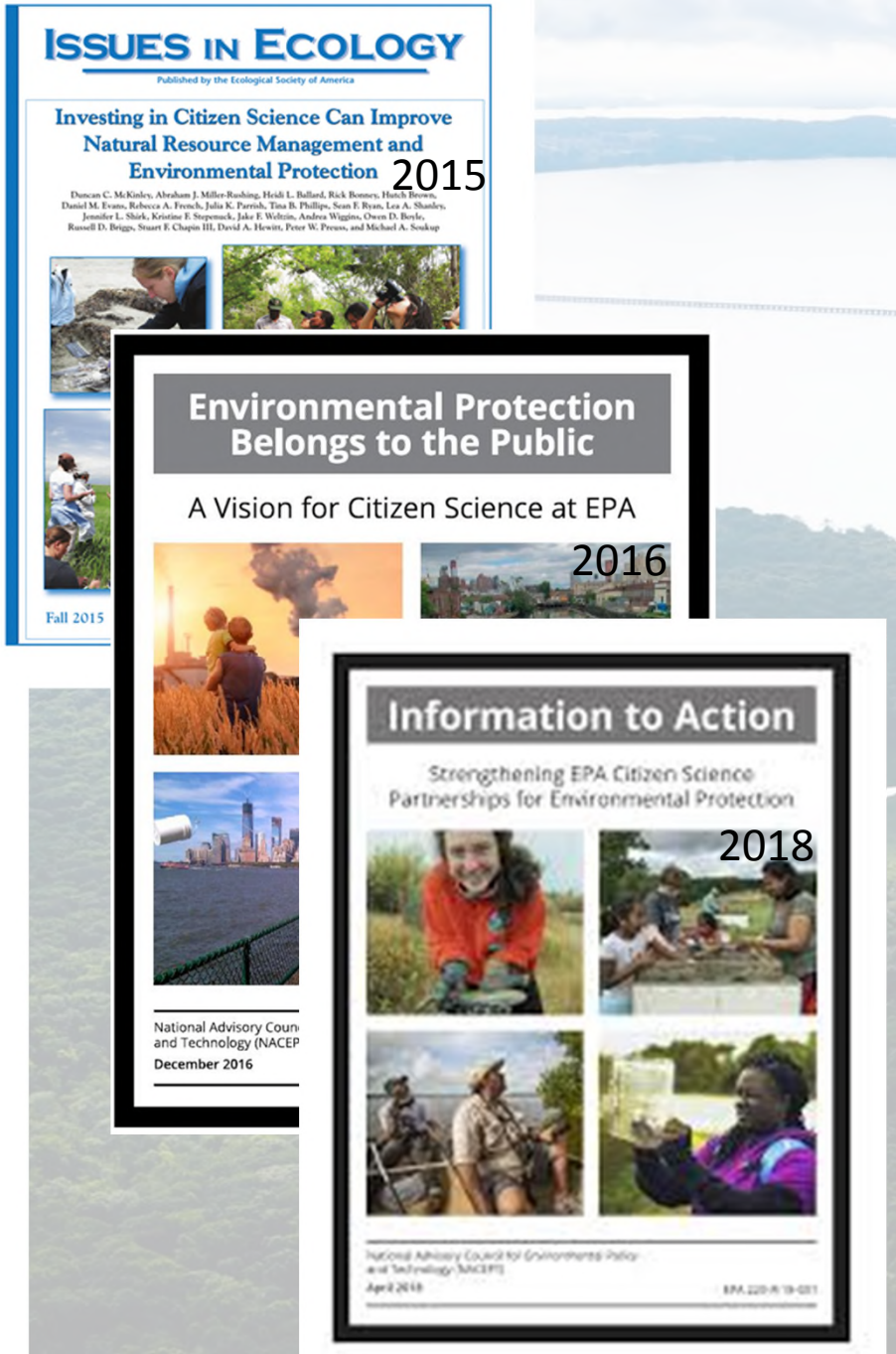
Tools

- Tiered framework
- Standardized QAPPs and monitoring protocols
- Training



Chesapeake Bay Program
Science. Restoration. Partnership.

Leadership endorsed (2018)!



CMC Chesapeake Monitoring Cooperative

Citizen and Nontraditional Partner Monitoring 2015-present

Photo courtesy of the Chesapeake Bay Program

Chesapeake Monitoring Cooperative

A partnership that aims to provide technical, logistical, and outreach support for the integration of volunteer-based and nontraditional water quality and benthic macroinvertebrate monitoring data into the Chesapeake Bay Program (CBP) partnership.

Cooperative Agreement

Alliance for the Chesapeake Bay

Chesapeake Bay Program
Science. Restoration. Partnership.

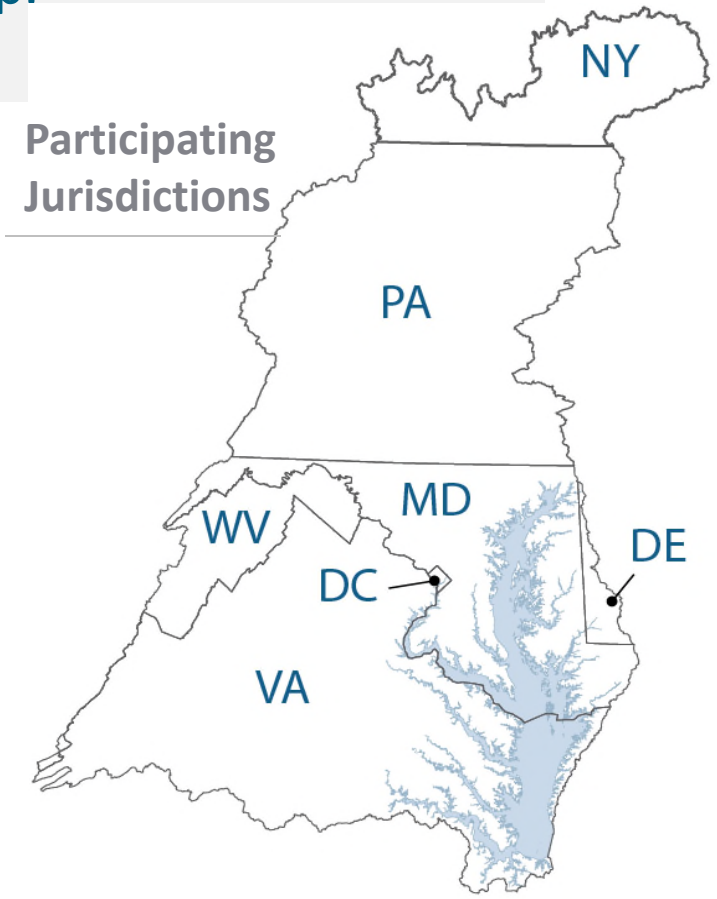
CMC development team partners & service providers

The Izaak Walton League of America — Defenders of Soil, Air, Woods, Waters and Wildlife

Alliance for Aquatic Resource Monitoring — ALLARM — est. 1986

University of Maryland
Center for Environmental Science

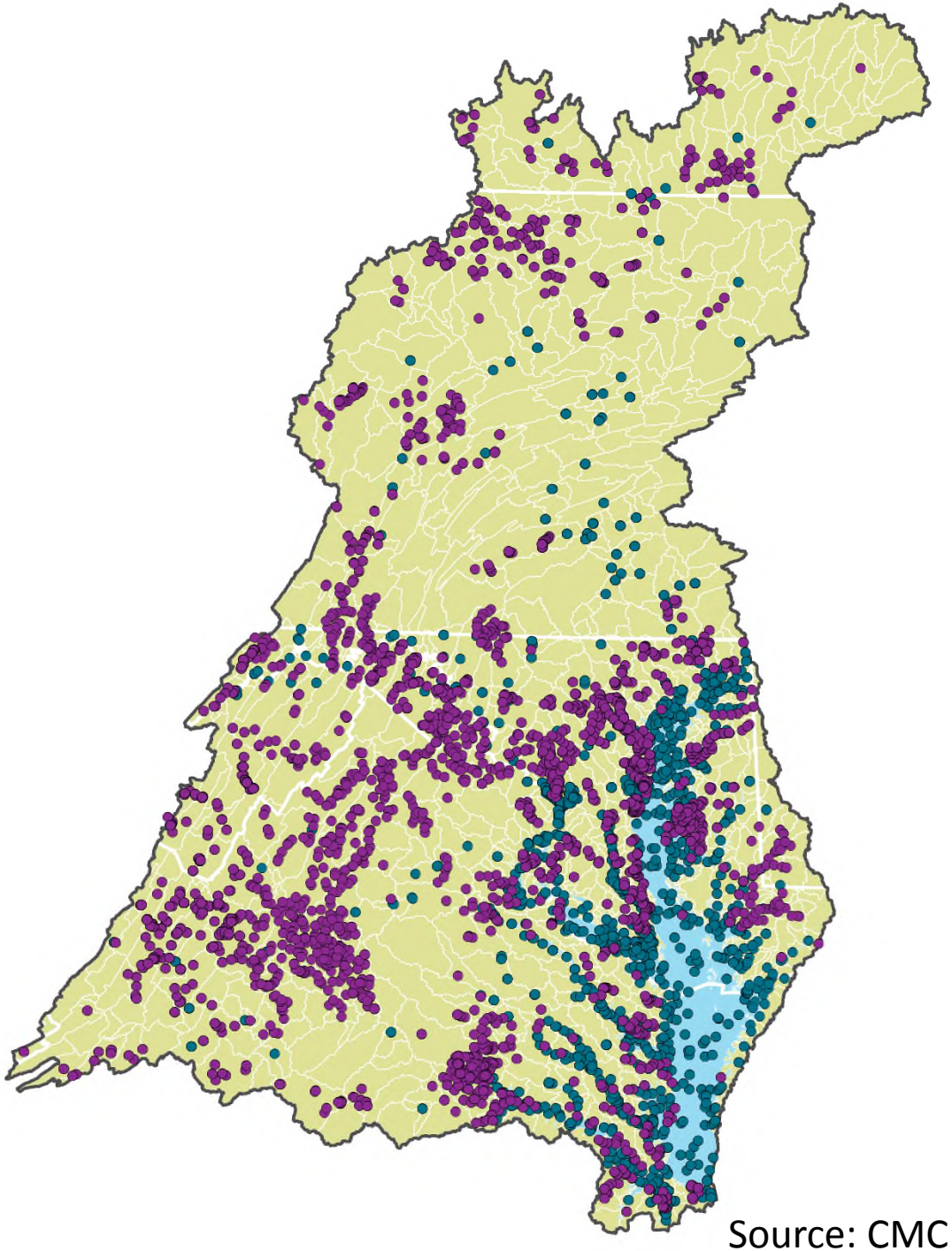
Participating Jurisdictions



Preliminary site coordinates of nontraditional (aka volunteer) monitoring

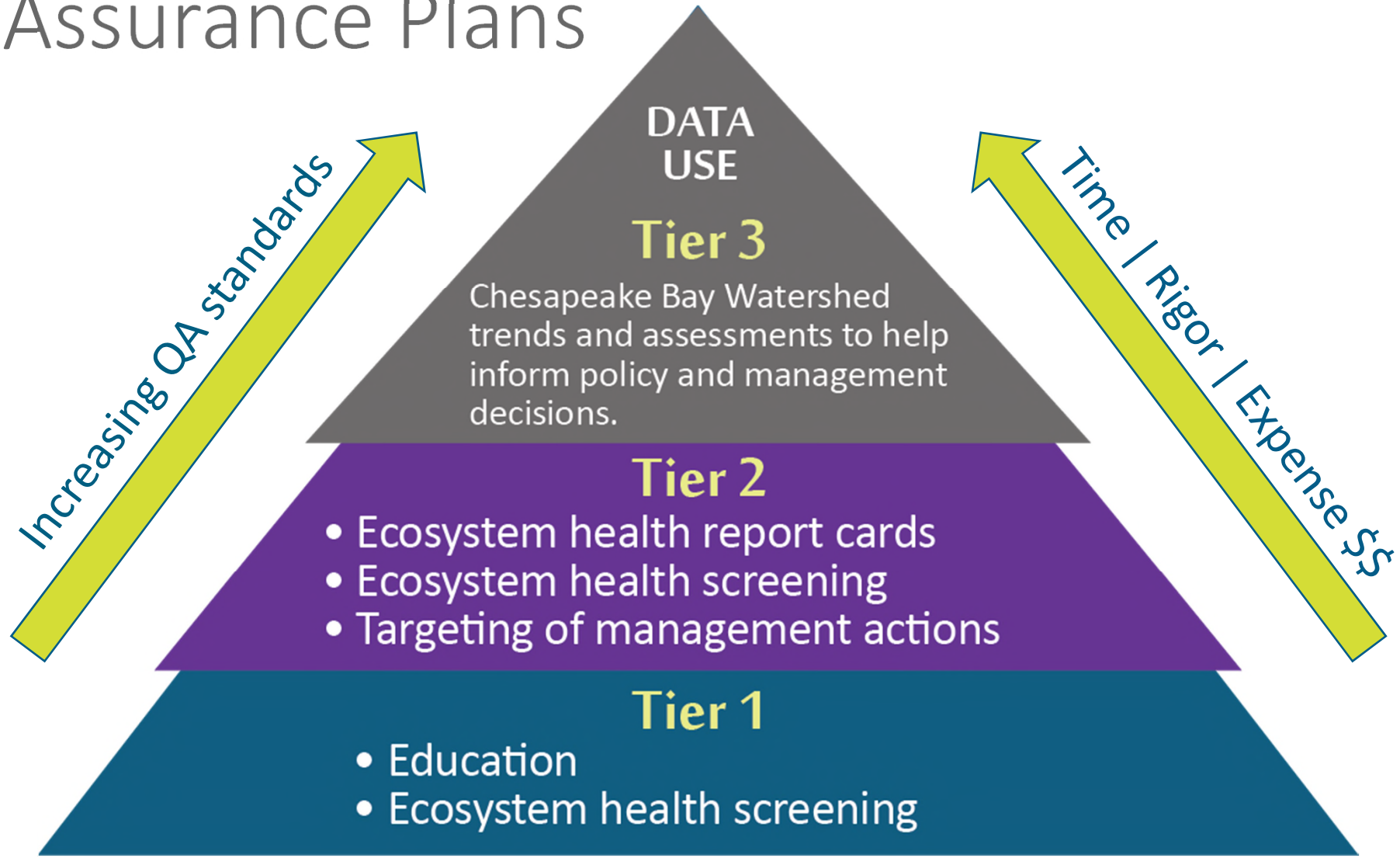
Traditional Sites

Nontraditional Sites

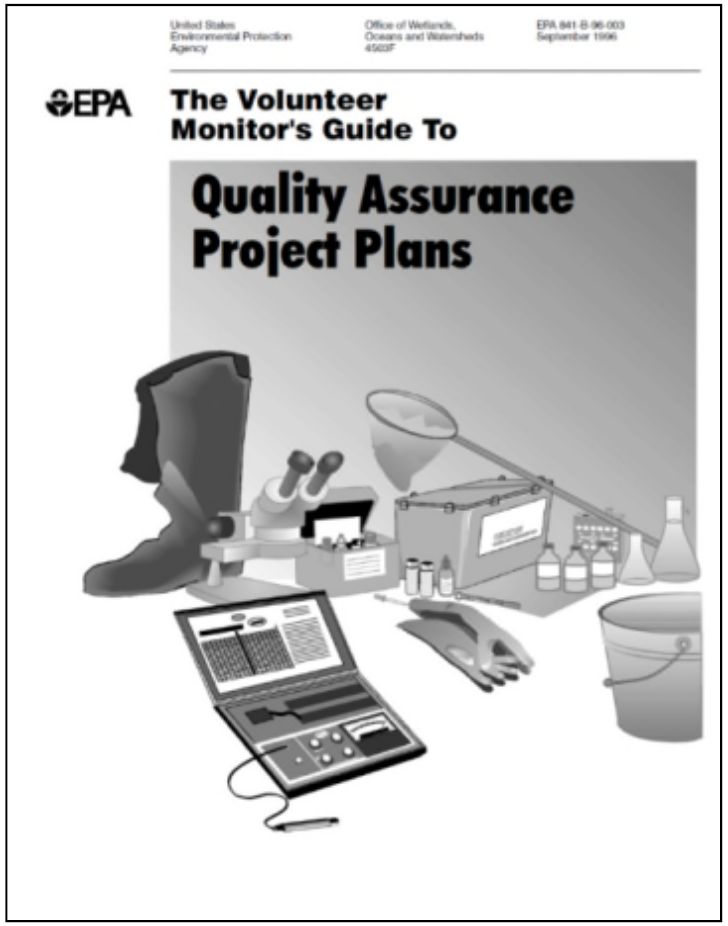


Source: CMC

Collecting data of known quality supported by Quality Assurance Plans



Quality Assurance Project Plans



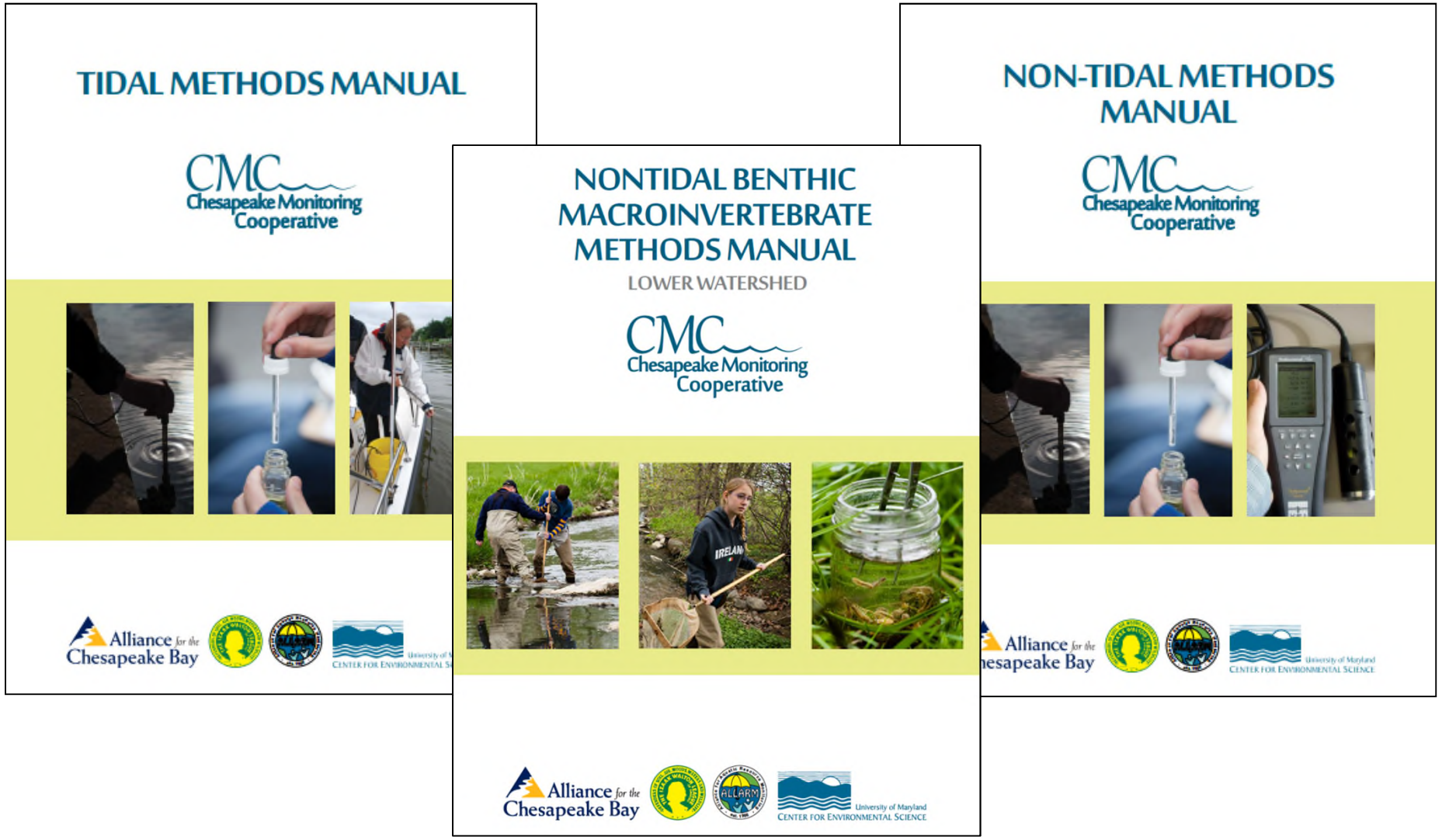
Water Quality Monitoring:
Tidal streams (Tier 1 & 2)
Nontidal streams (Tier 1 & 2)

Benthic Macroinvertebrate Monitoring:
Nontidal wadable streams (Tier 1 & 2)

Approved by EPA

Chesapeake Bay Program
Science. Restoration. Partnership.

User-friendly Method Manuals



Chesapeake Data Explorer: A central database for Chesapeake volunteer monitoring data

Mapping!

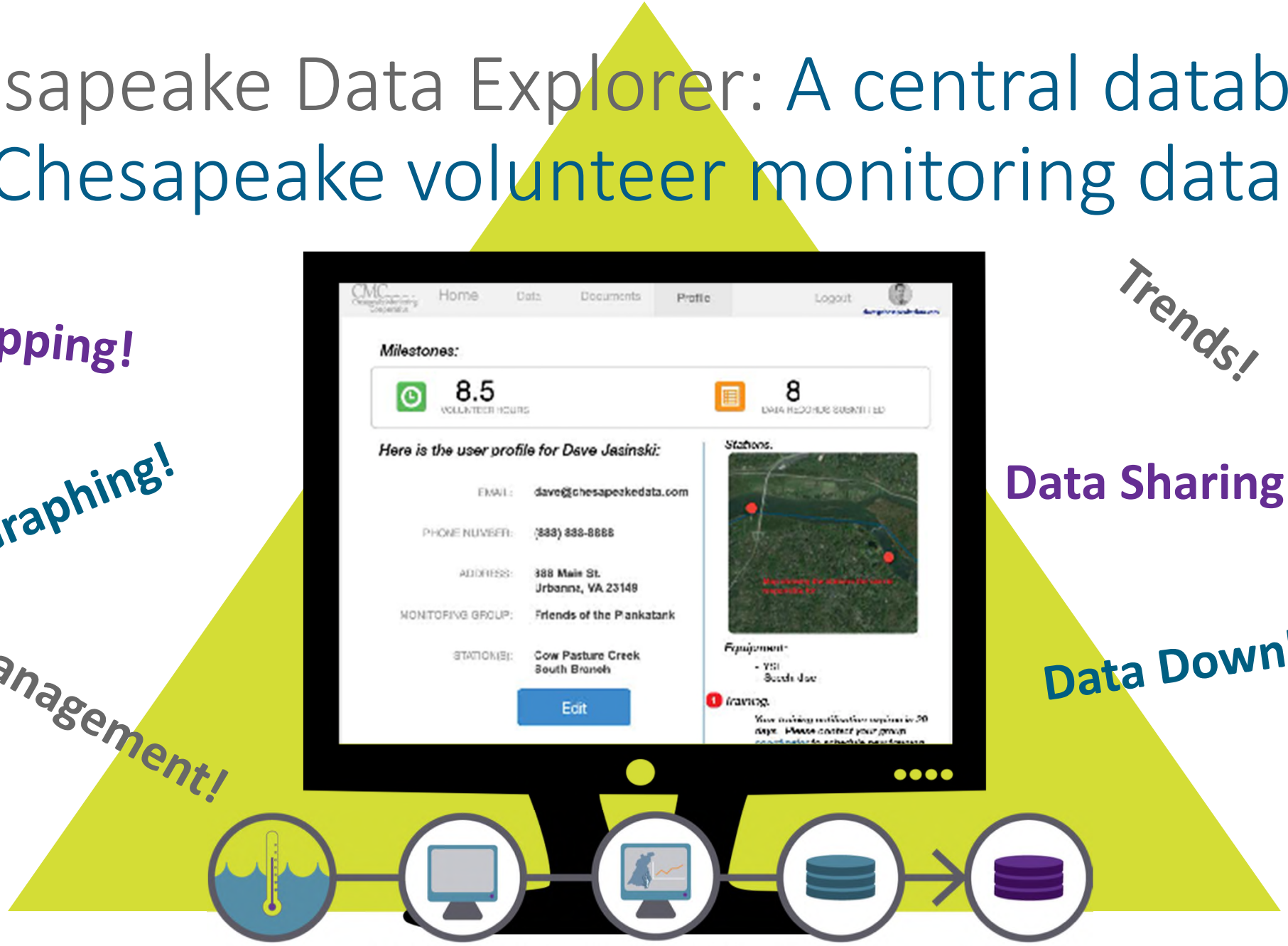
Graphing!

Data Management!

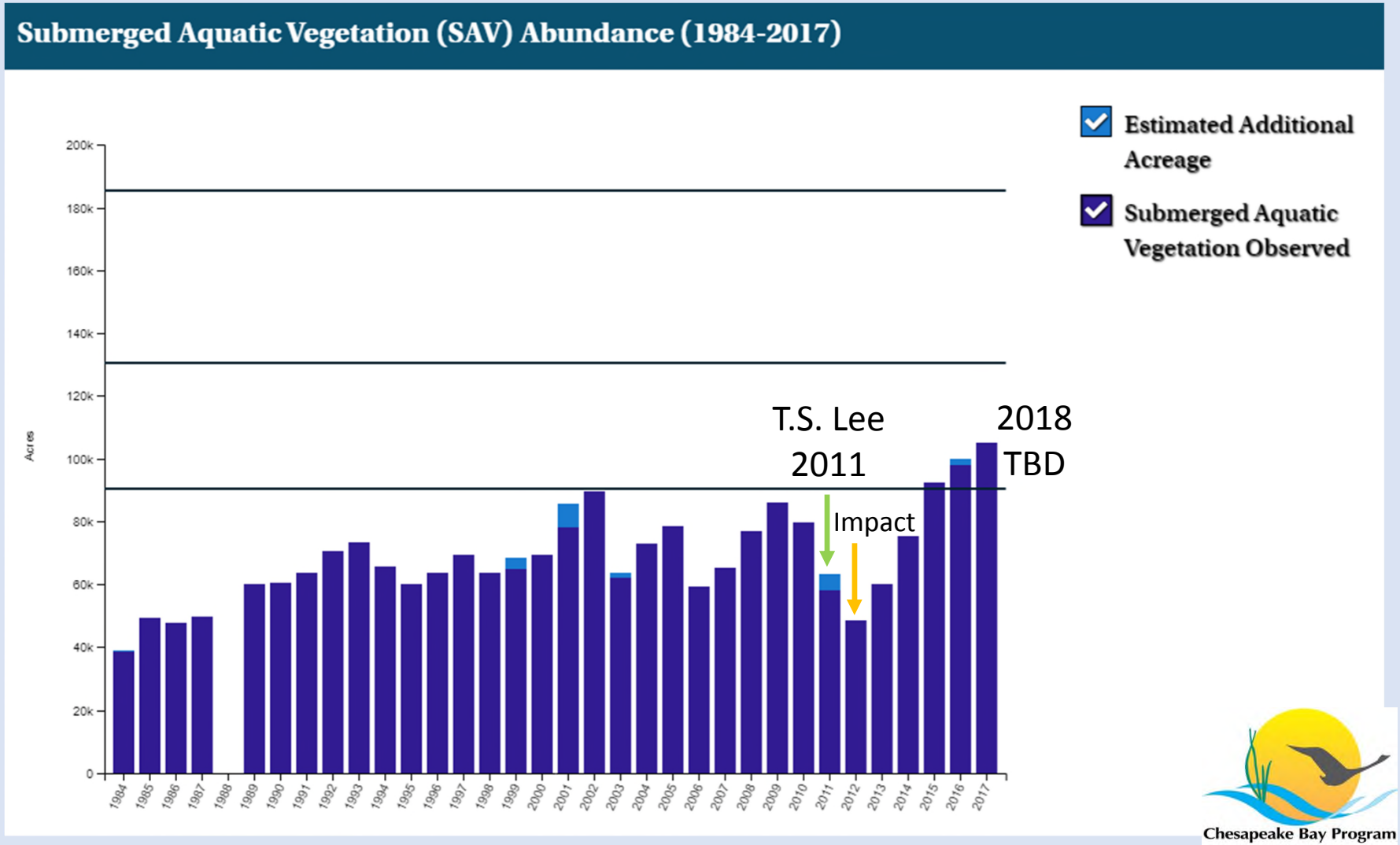
Trends!

Data Sharing!

Data Download!

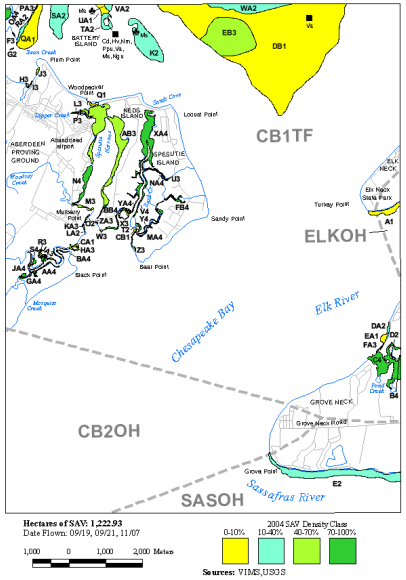


Advancing Submerged Aquatic Vegetation (SAV) assessments 1984-present



Chesapeake Bay Program
Science. Restoration. Partnership.

Data drive management and policy decisions.
E.g. Submerged Aquatic Vegetation:
Habitat Assessment and Restoration Targeting.
1984-present aerial surveys



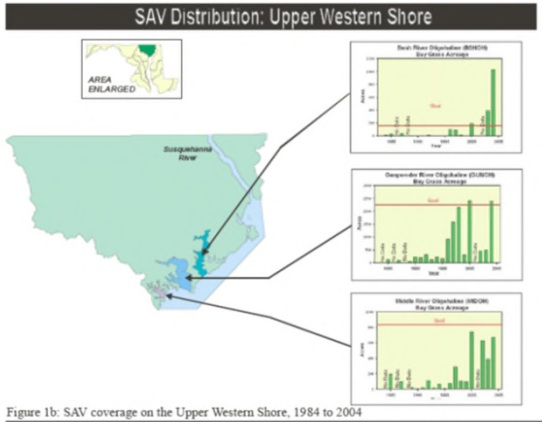
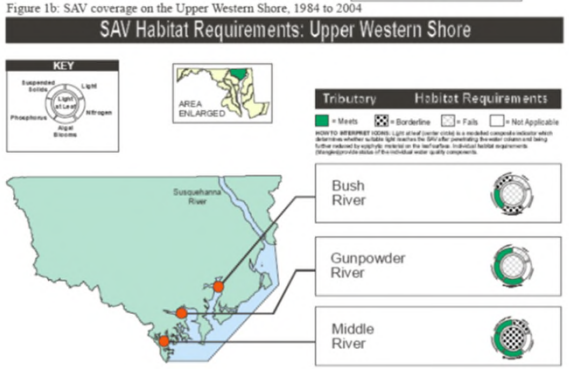


Figure 1b: SAV coverage on the Upper Western Shore, 1984 to 2004



PNAS
Proceedings of the National Academy of Sciences of the United States of America

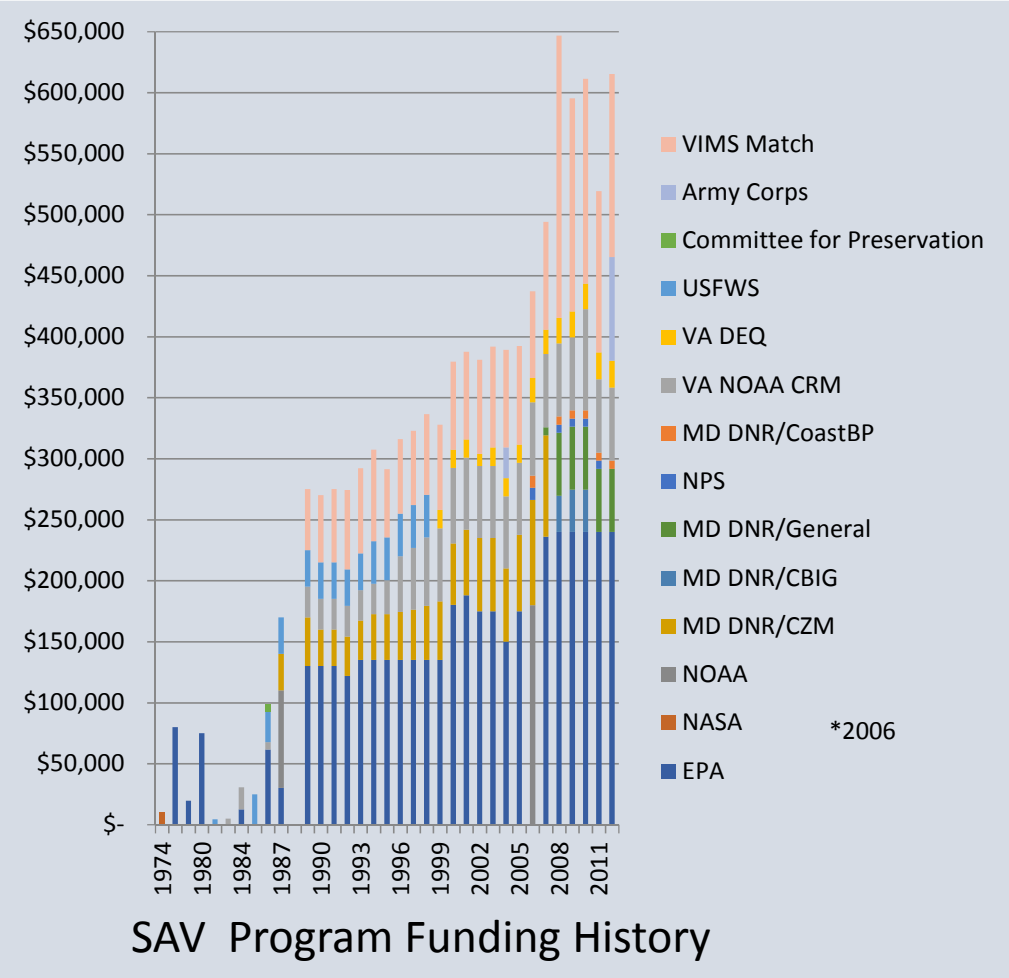
Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region

Jonathan S. Lefcheck, Robert J. Orth, William C. Dennison, David J. Wilcox, Rebecca R. Murphy, Jennifer Keisman, Cassie Gurbisz, Michael Hannam, J. Brooke Landry, Kenneth A. Moore, Christopher J. Patrick, Jeremy Testa, Donald E. Weller, and Richard A. Batiuk

PNAS April 3, 2018 115 (14) 3658-3662; published ahead of print March 5, 2018
https://doi.org/10.1073/pnas.1715798115

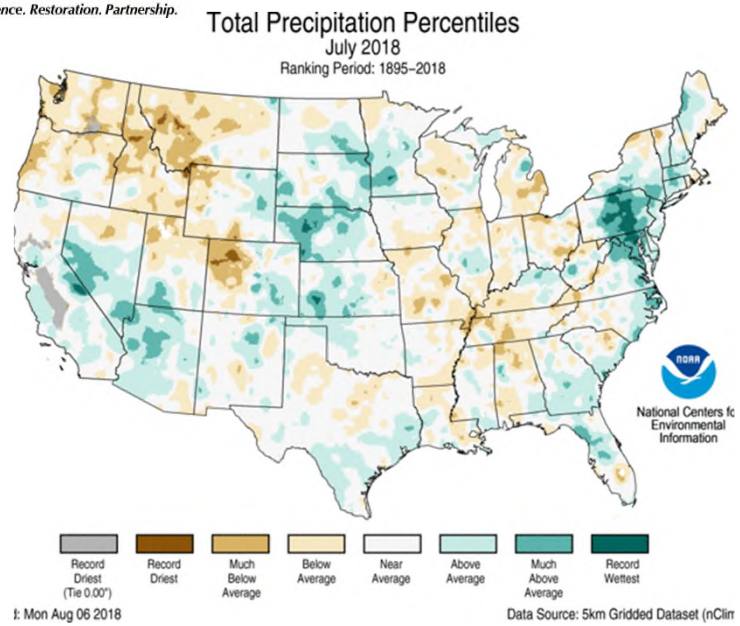
Edited by Nancy Knowlton, Smithsonian Institution, Washington, DC, and approved January 25, 2018 (received for review September 7, 2017)

Challenges: Sustaining growth.
Baywide SAV Survey Funding History



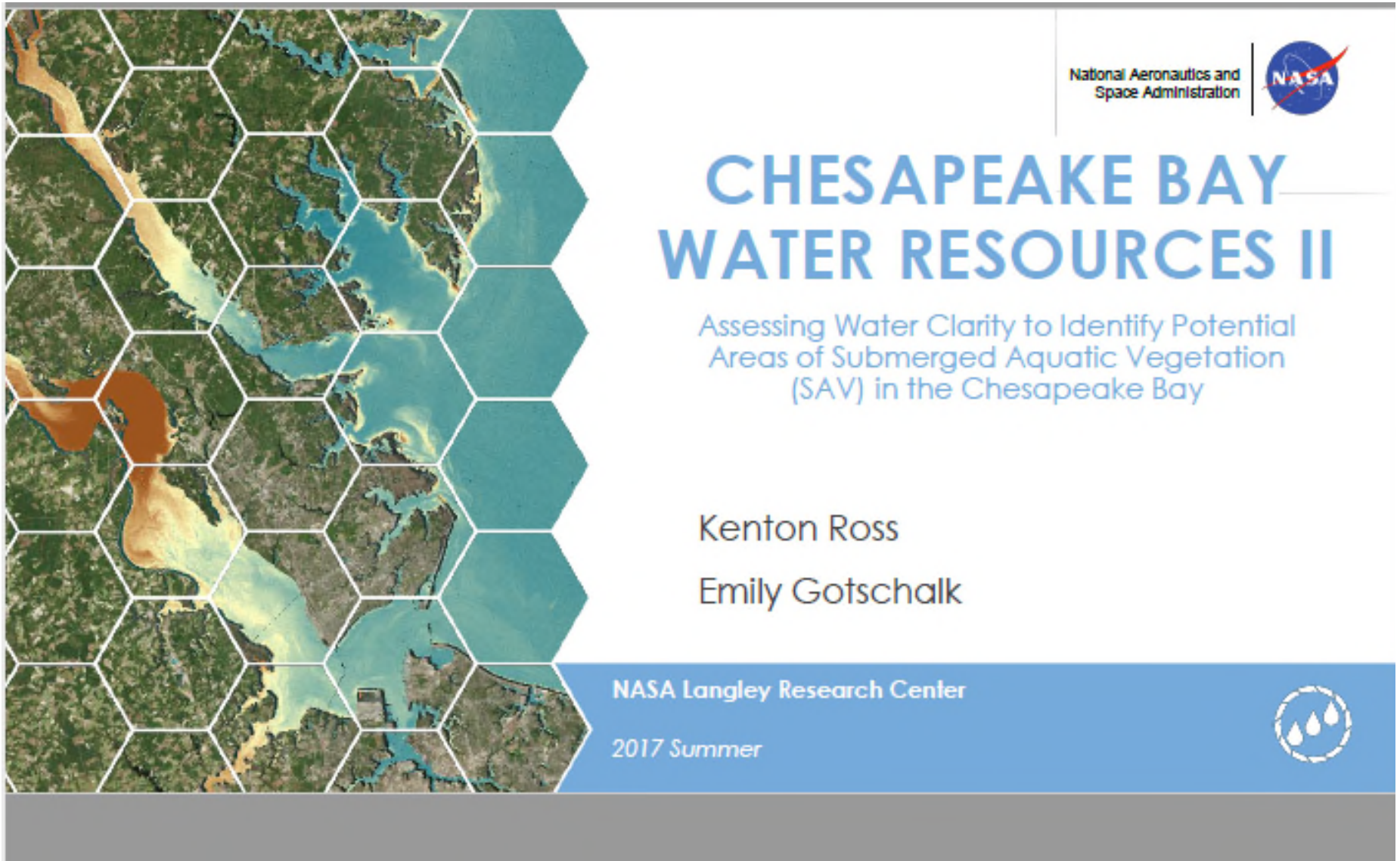
- Stepwise increased costs in response to management-driven requests for products
- Near- , mid- and long-term challenges to funding pools.

Chesapeake Bay Program
Science. Restoration. Partnership.



SAV monitoring program challenges peaked with 2018 summer and autumn storms. Can we improve our protocol for assessment?

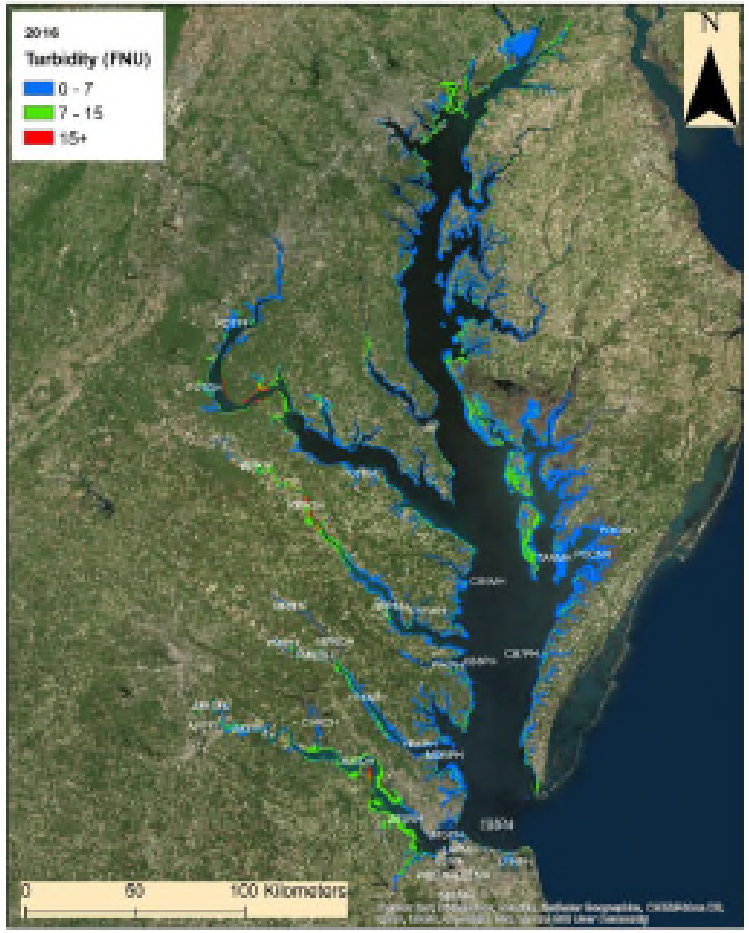
Recent NASA collaborations on potential protocols for using satellite imagery:
NASA DEVELOP program output



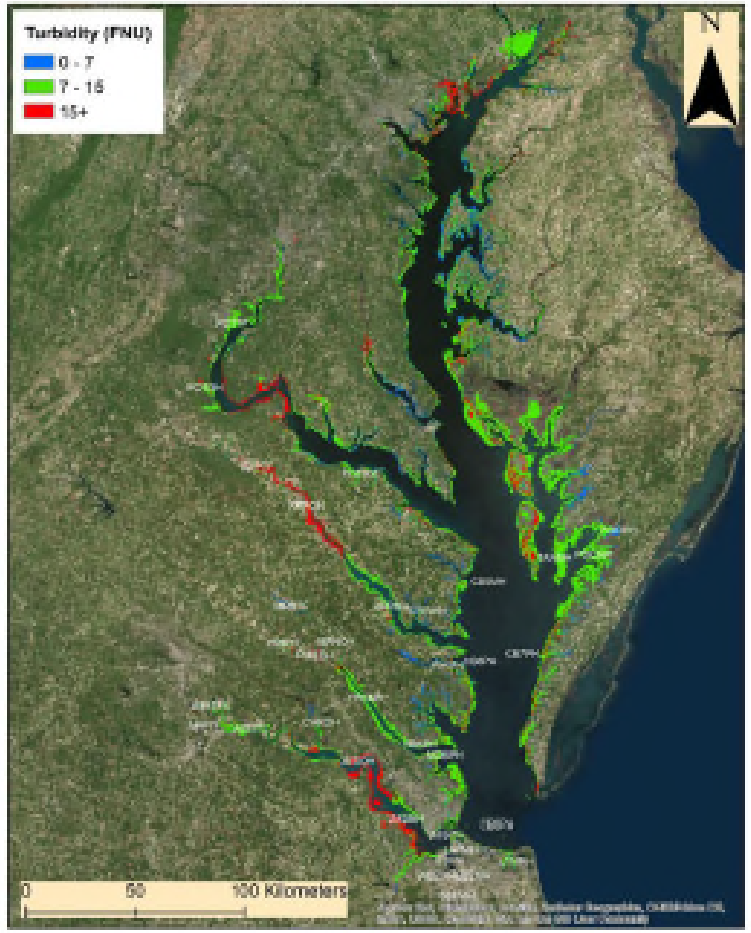
Opportunities for baywide water quality standards attainment assessment applications: water clarity

Empirical Correction (2016)

Average 2m Turbidity (2016)



Average 2m Turbidity (2016)

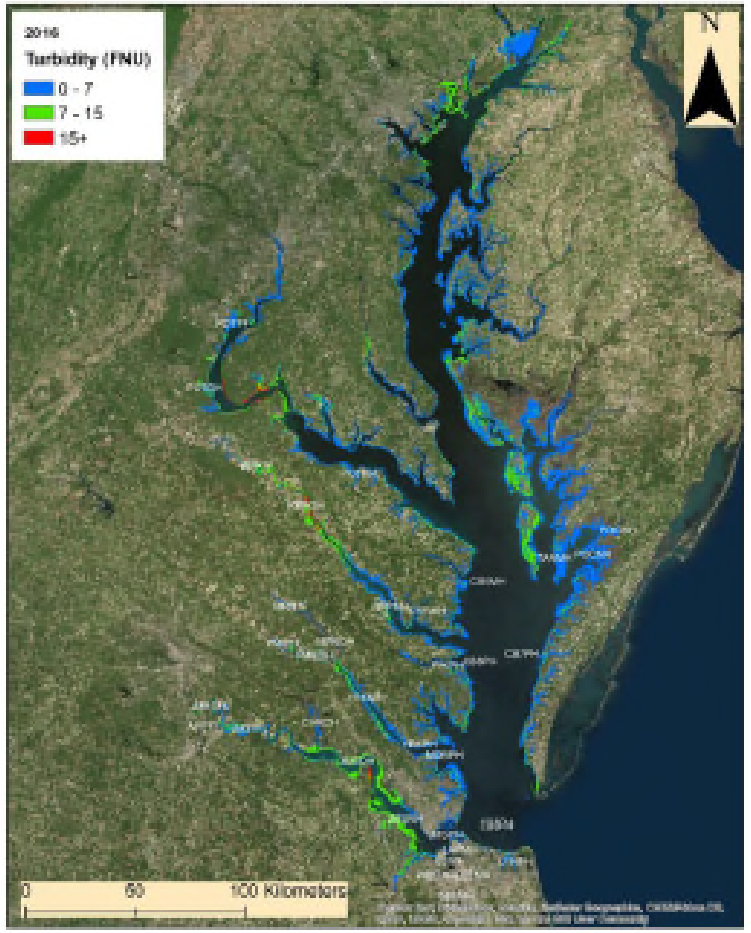


Funded for 2019-2020!

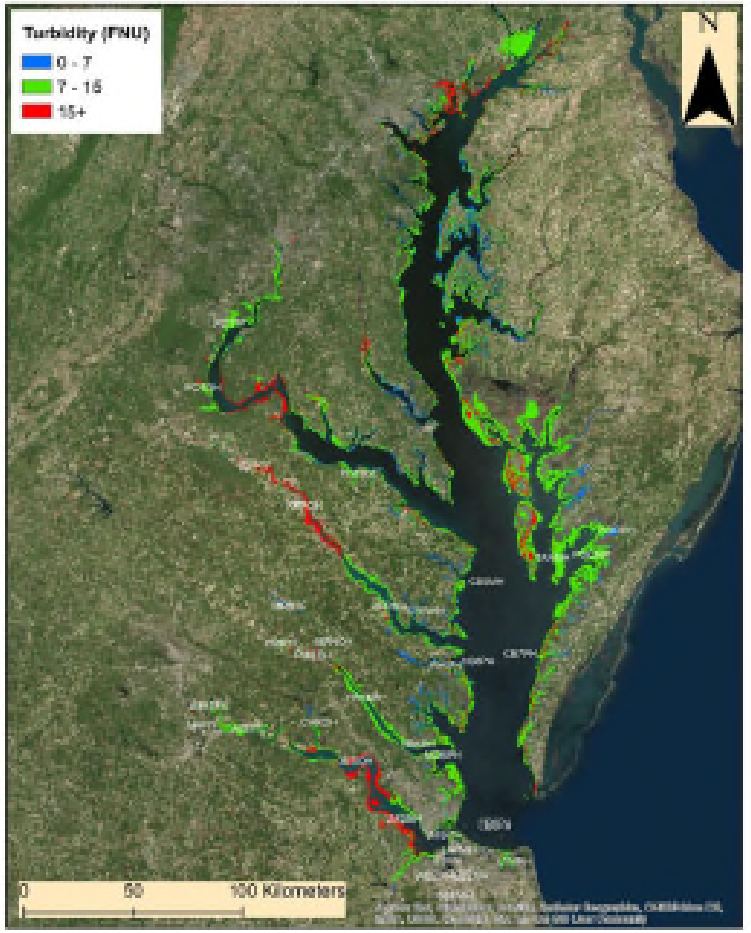
Community workshop on developing protocol for satellite data acquisition, storage, interpretation and communication

Empirical Correction (2016)

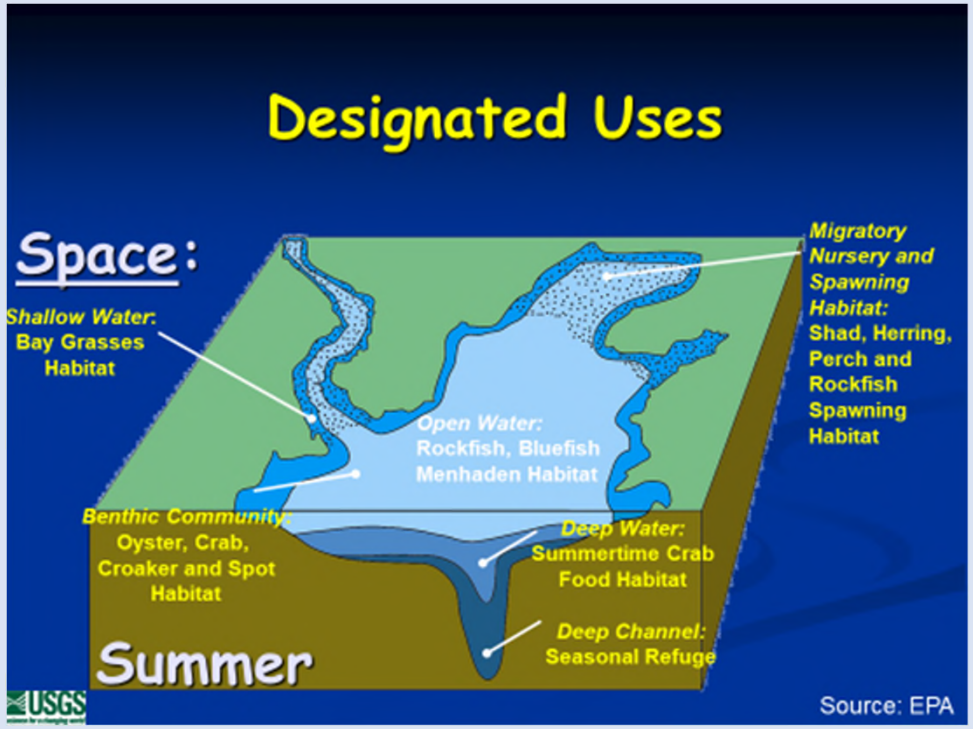
Average 2m Turbidity (2016)

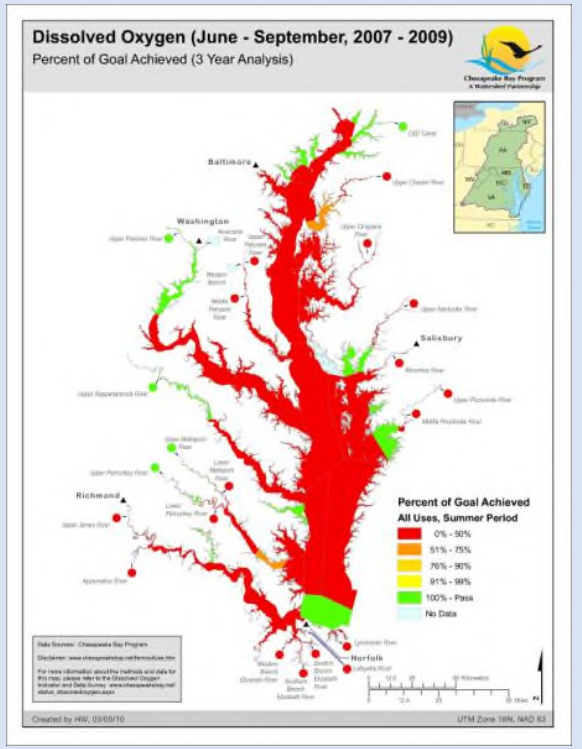


Average 2m Turbidity (2016)

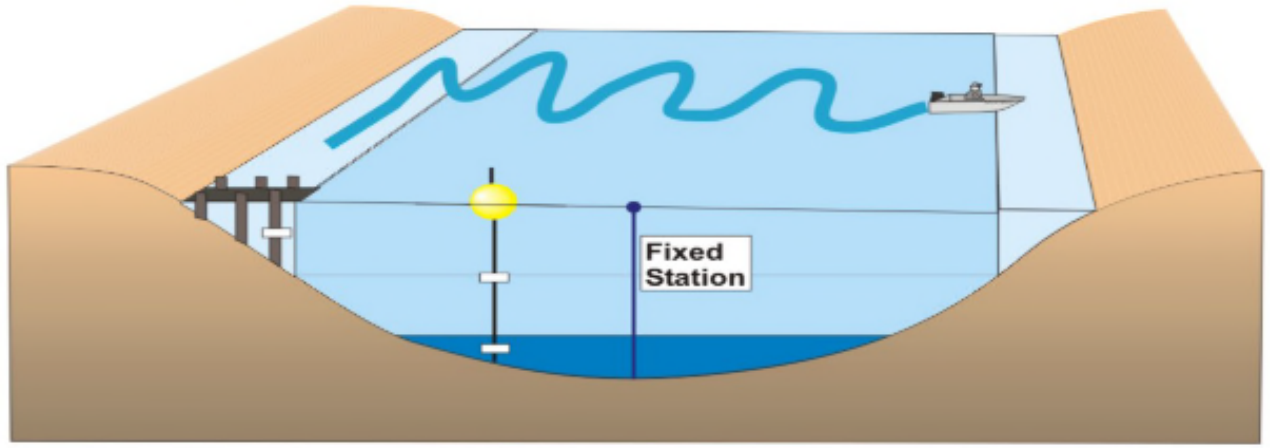


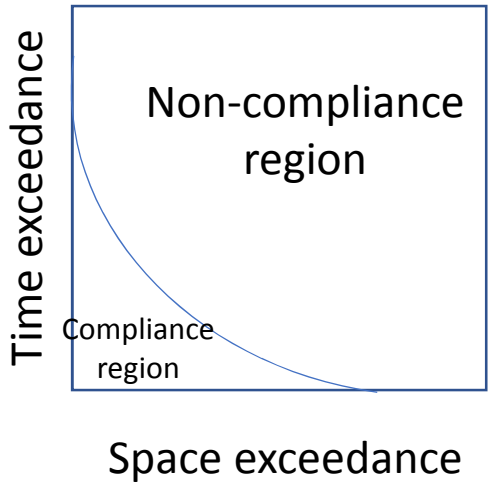
Advancements: Assessing Incremental Progress using Chesapeake Bay Water Quality Standards Non-Attainment Results





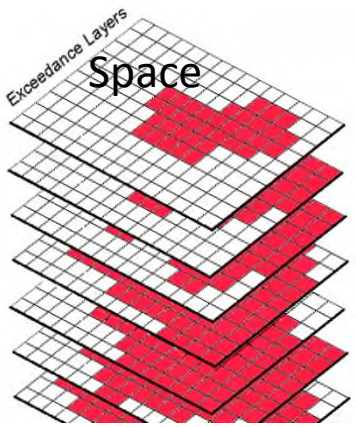
Orientation for the CB Criteria Assessment Framework: Historically binary results.

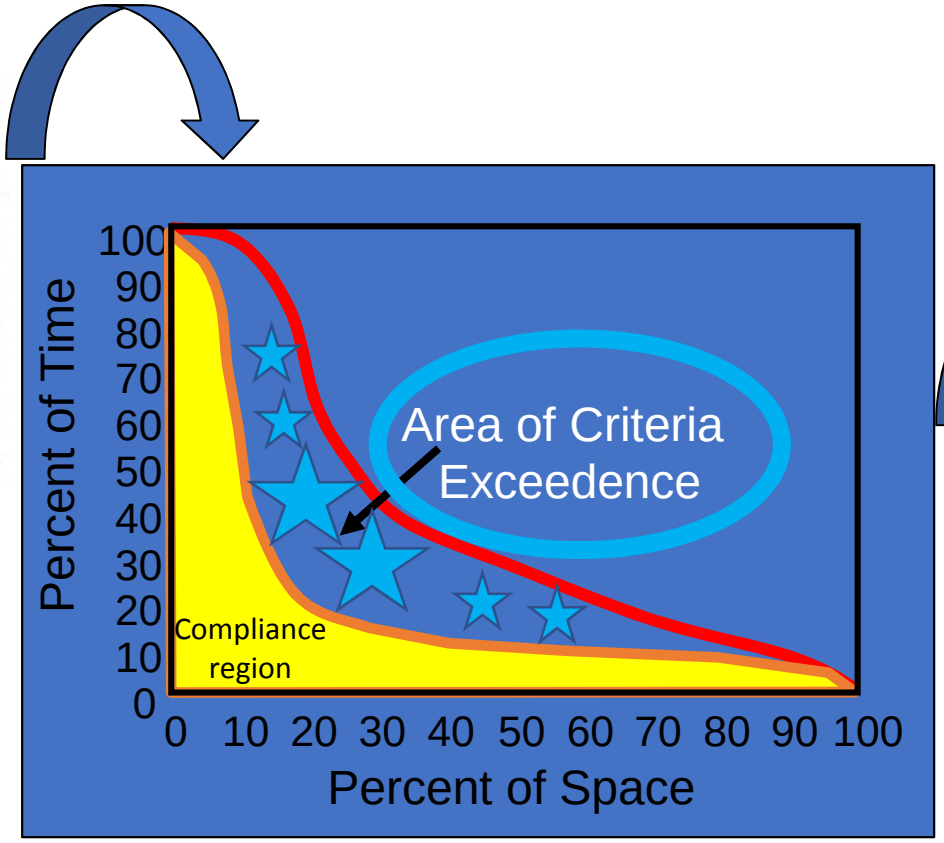




Chesapeake Bay Water Quality Criteria Assessment

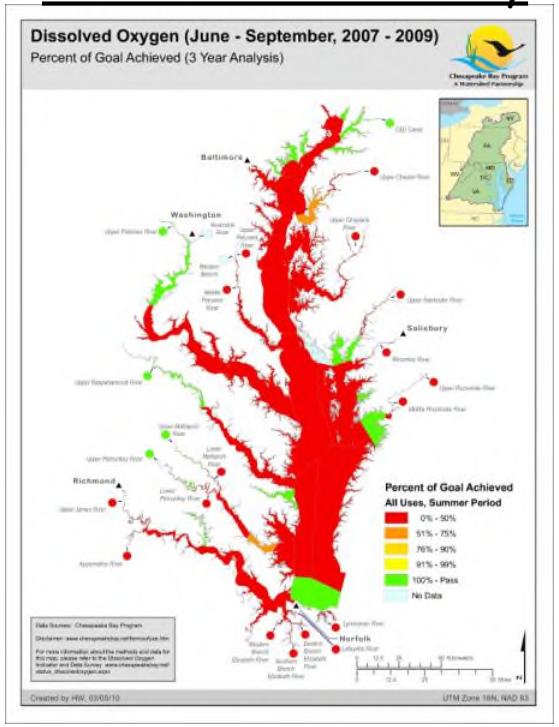
Multiple surveys through Time





Water Quality Standards Attainment

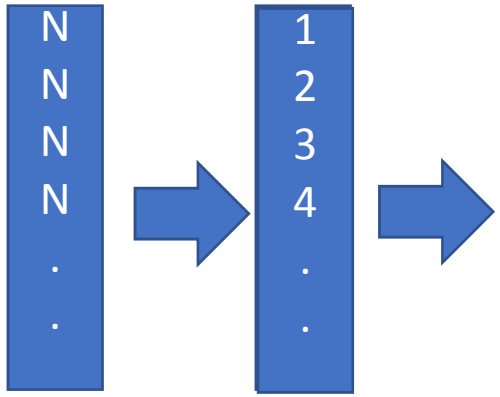
Assessment Summary



Visualizing Chesapeake Bay Assessment of Criterion Attainment Deficit

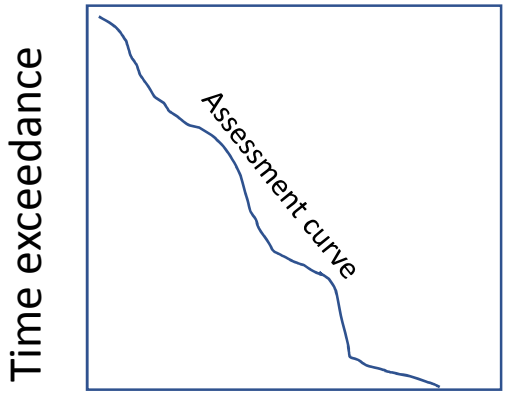
Dissolved oxygen 30 day mean example

Assessment Analysis Of Monitoring Data[1]



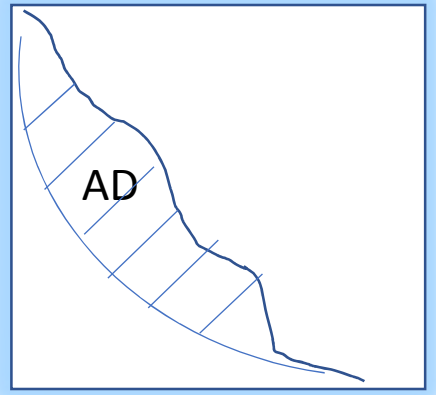
Monitoring
3 yr monthly means

Assessment & Ranked violations



Space exceedance

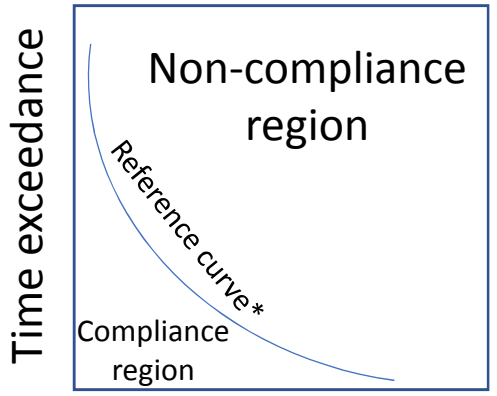
*Extracting more information from the analysis.



AD. Area of non-compliance = the difference between assessment and reference curves (i.e., "**A**ttainment **D**eficit").

Compliance Decision Framework[2]

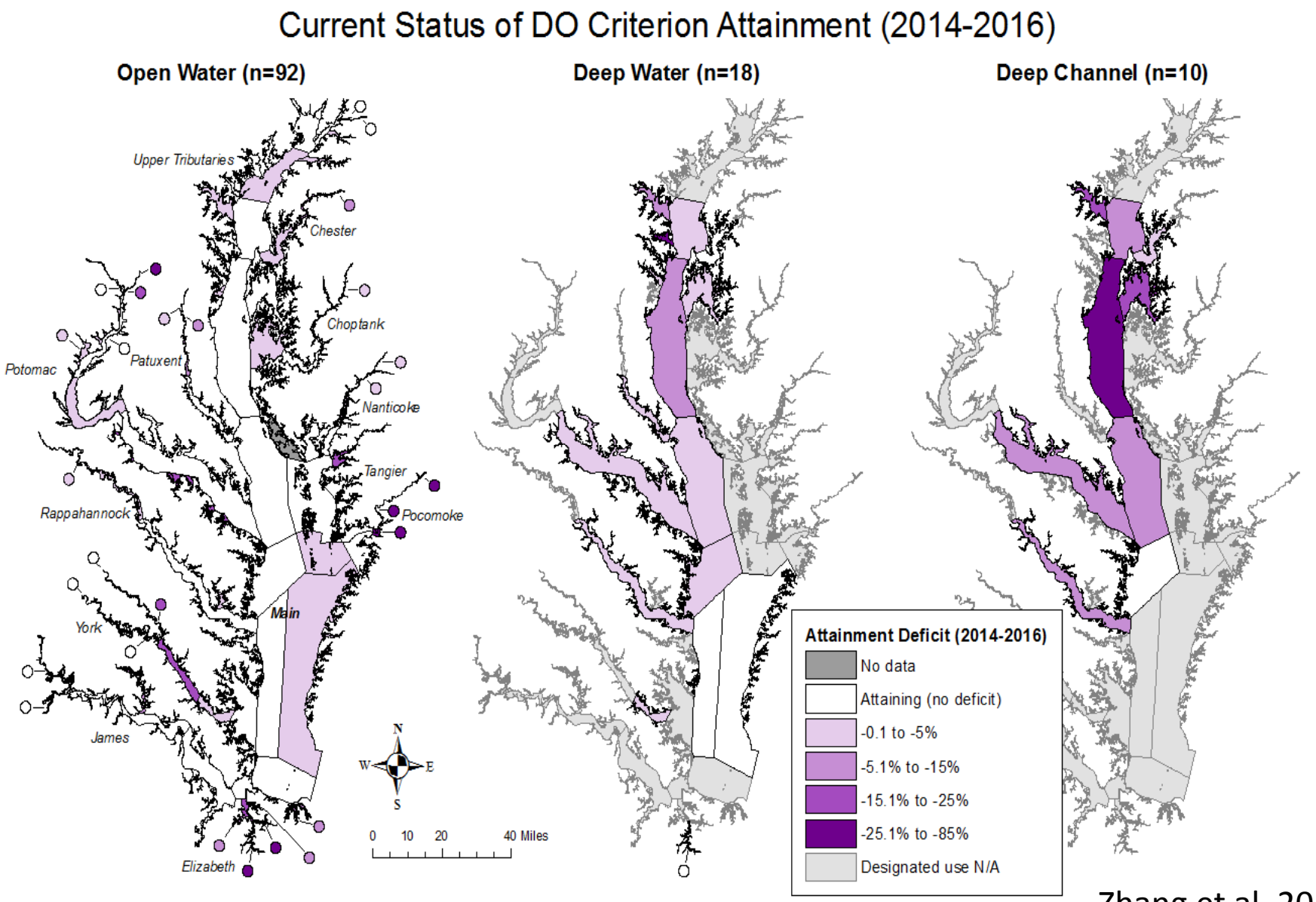
Space exceedance



*Reference curve – Allowable non-compliance threshold

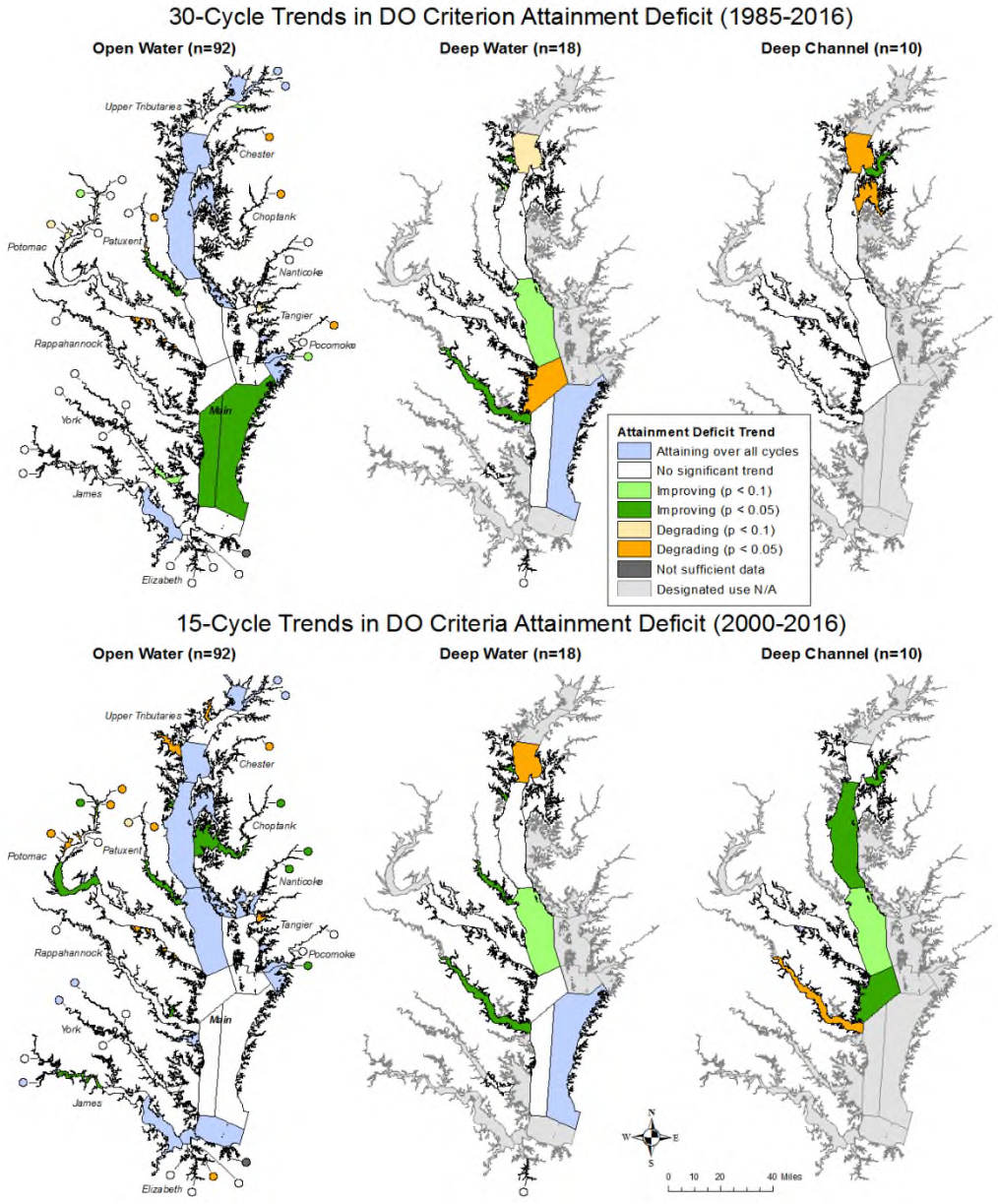
1. USEPA 2003, Tango and Batiuk 2013
2. USEPA 2003, Batiuk et al. 2009

Advancements: Communicating STATUS – large regions attaining select criteria, large number of areas non-attaining of water quality standards.



Zhang et al. 2018 Front. Mar. Sci.

Advancements: Attainment deficit assessment has improved communicating status and trends – long and short term for area managers.

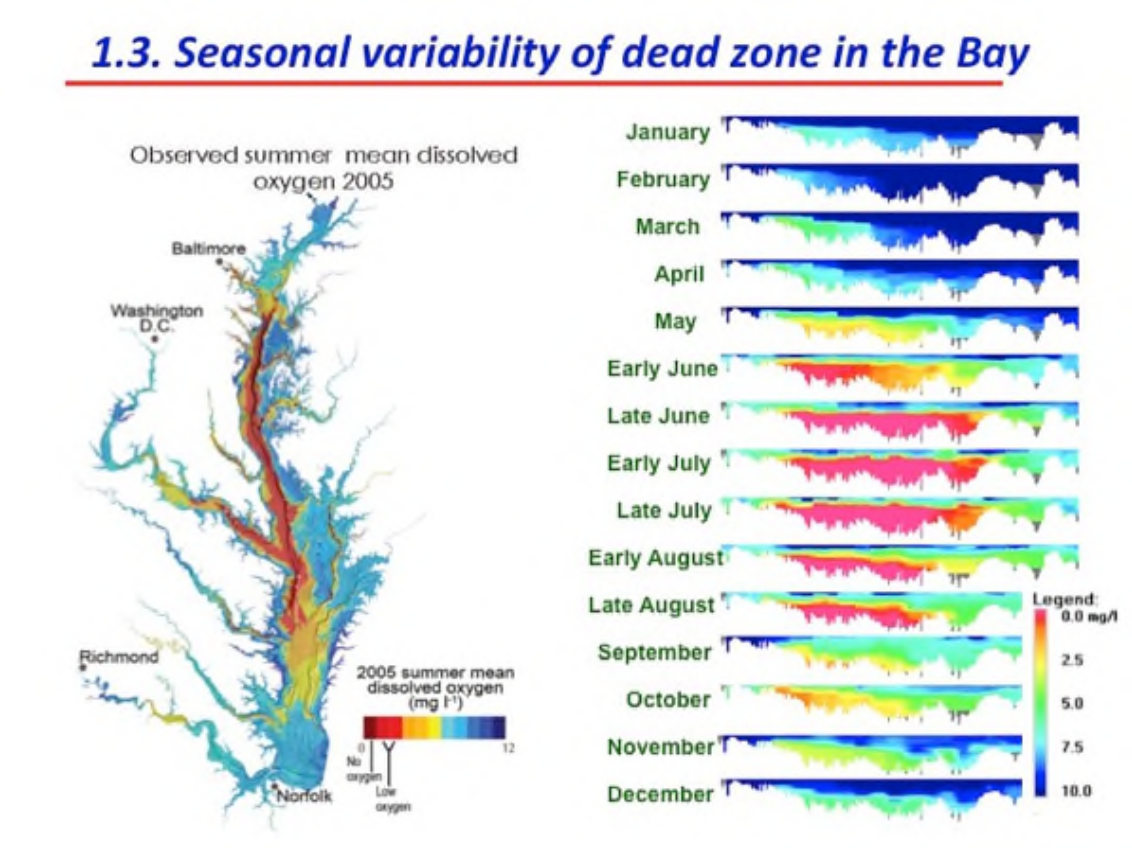


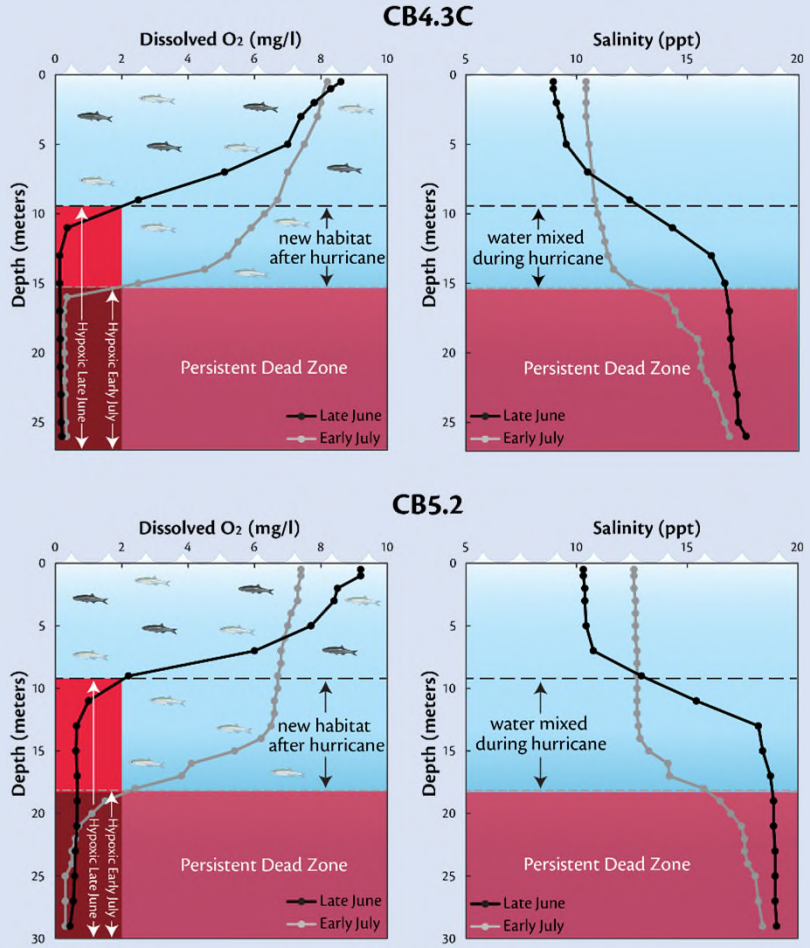
Long-term baywide TRENDS
Mixed picture of stable, improving and degrading conditions.

Short-term TRENDS

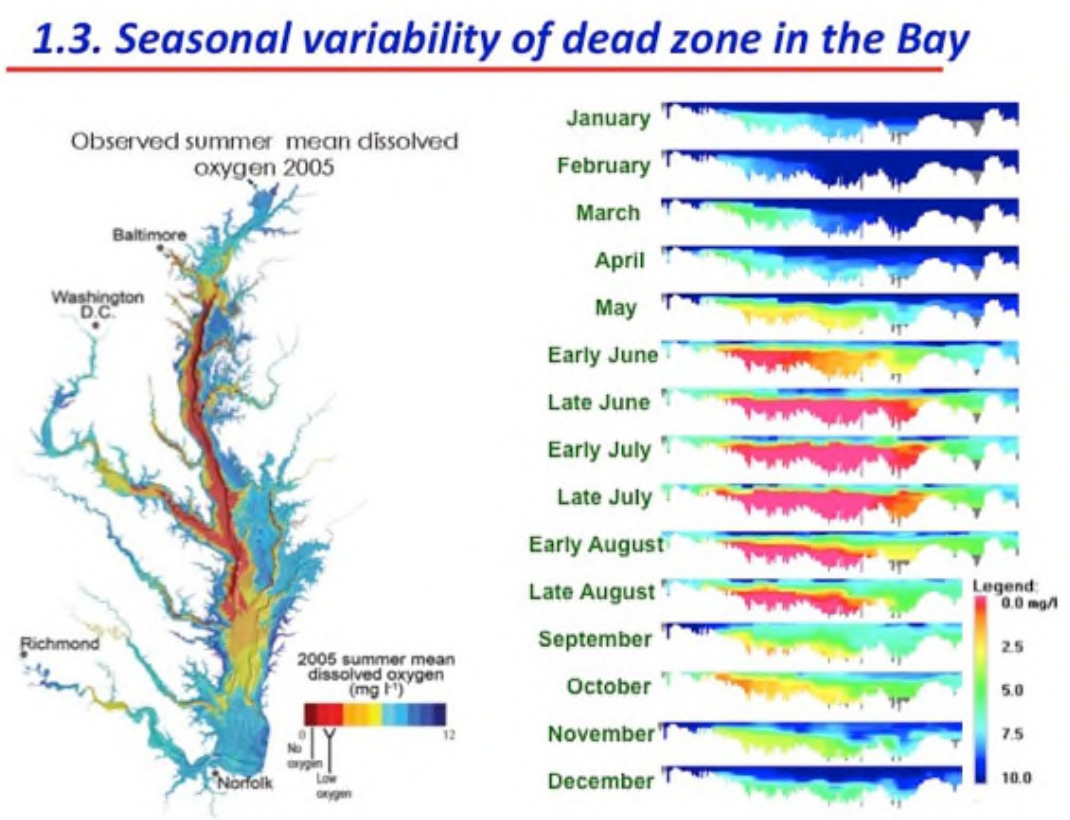
Zhang et al 2018 Front. Mar. Sci.
Maps by E. Trentacoste

Advancements toward real time hypoxia monitoring and assessment



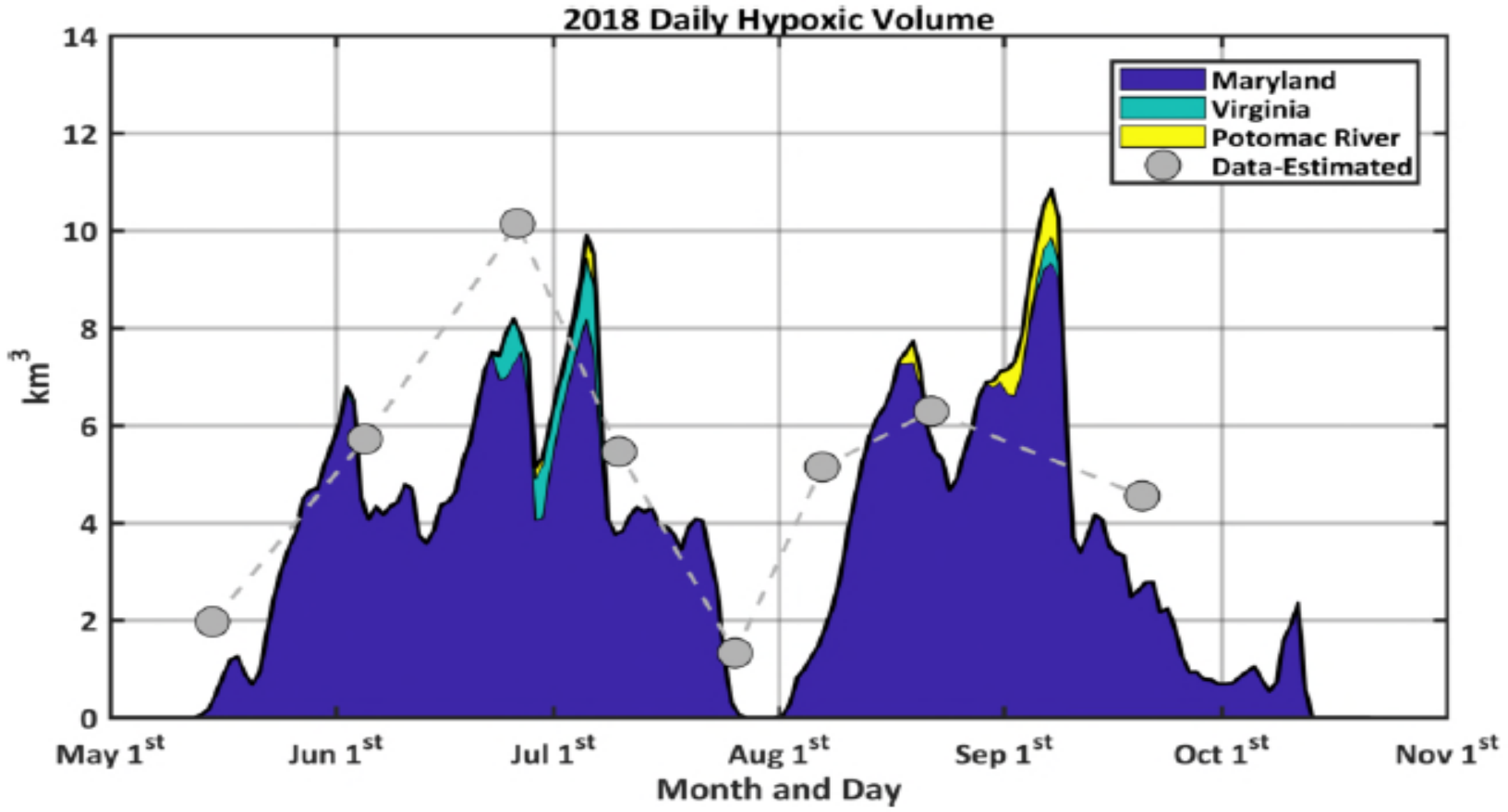


Advancements toward real time hypoxia monitoring and assessment



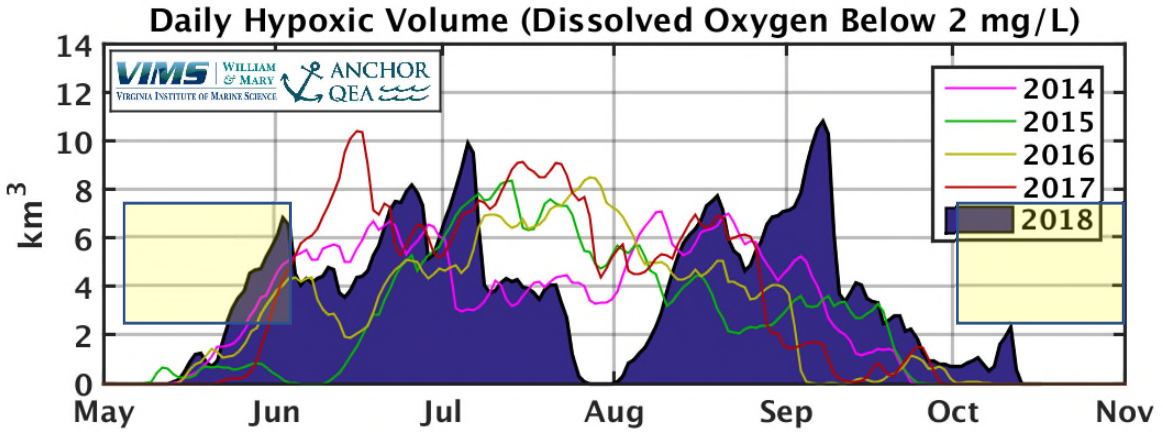
- Long term monitoring includes monthly sampling with biweekly sampling during June-September.
- Model-based assessments suggested important differences from biweekly monitoring estimates.

2018. Virginia Institute of Marine Science model based hypoxia assessment captured peak hypoxia missed by monitoring



Tracking information at: https://www.vims.edu/research/topics/dead_zones/forecasts/cbay/index.php

2018 hypoxia through model-based assessment shows full event duration goes beyond the summer season.

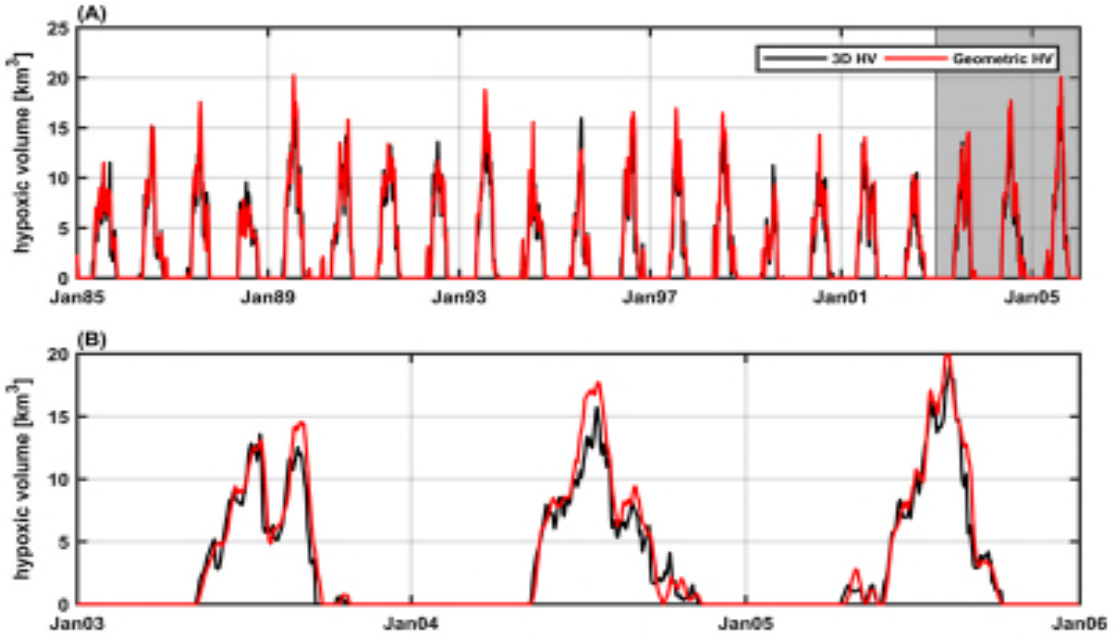


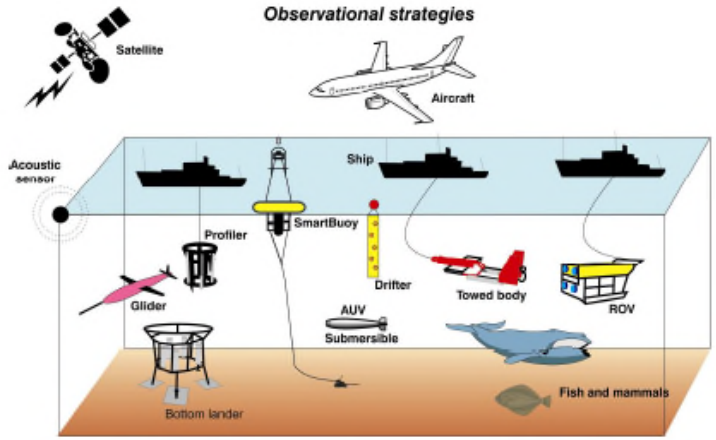
This is an important consideration for water quality standards attainment assessments perspective where summer season is described as June-September

http://www.vims.edu/research/topics/dead_zones/forecasts/cbay/hypoxic-volume/index.php

Bever et al. (2018) further show from model-based assessments that we can effectively estimate and track hypoxic volume in the Chesapeake Bay Using *two continuously sampled oxygen profiles.*

Estimating Hypoxic Volume in the Chesapeake Bay Using Two Continuously Sampled Oxygen Profiles



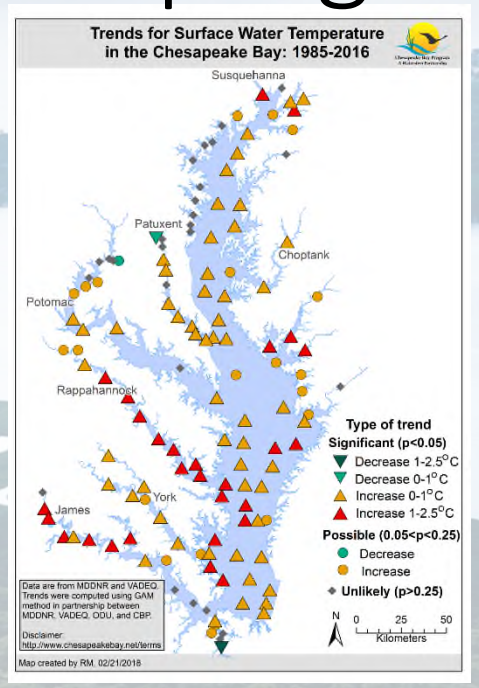


*Advancements: In 2019, the Chesapeake Bay Trust is funding a pilot study of profile assessment technology. Data are expected to support calibrating and validating the model results for hypoxia estimation in Chesapeake Bay

Journal of Geophysical Research: Oceans, Volume: 123, Issue: 9, Pages: 6392-6407, First published: 27 August 2018, DOI: (10.1029/2018JC014129)

Additional directions for the program

- Climate indicator developments
  - GAMs applications (Murphy et al.)



- Stream health indicator development and targeting areas for data collections (Buchanan et al., Maloney et al.)

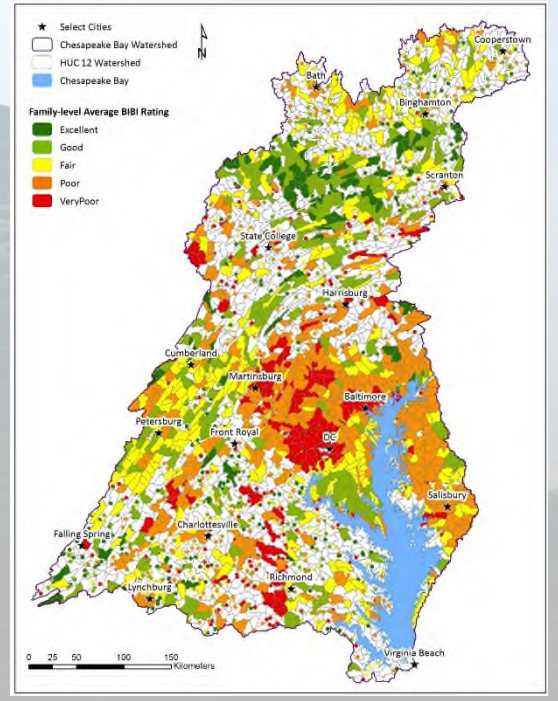


Photo courtesy of the Chesapeake Bay Program

Summary

- The monitoring program evolution continues by expanding partnerships now into the Citizen Science realm to address data resolution needs (space & time)
- Doing more with existing data resources is a common request from managers. We continue to extend data utility with new analysis approaches to support enhanced communication product development (e.g. Attainment deficit, GAMs applications)
- As technology improves, application are explored to improve status and tracking assessments of key ecosystem indicator (e.g. aquatic vegetation and hypoxia)
- Acknowledgements to the many dedicated scientists, analysts, managers, policy-makers of the Chesapeake Bay Program partnership

USGS science for a changing world

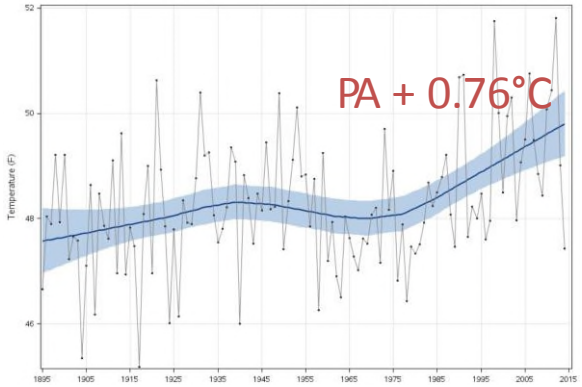
Chesapeake Bay Program
Science. Restoration. Partnership.

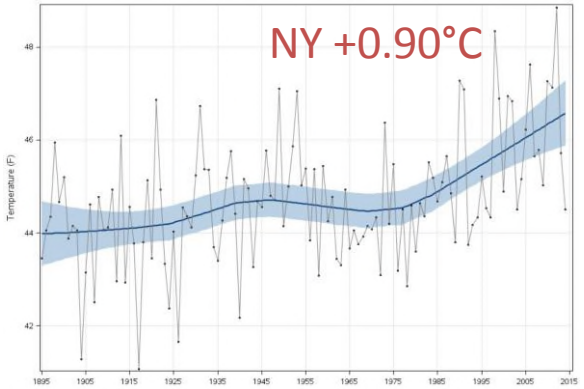
Chesapeake Bay Program
Science, Restoration, Partnership

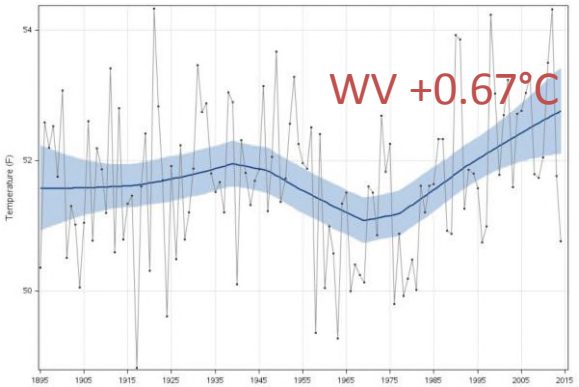
Temperature trends for the six CBP states

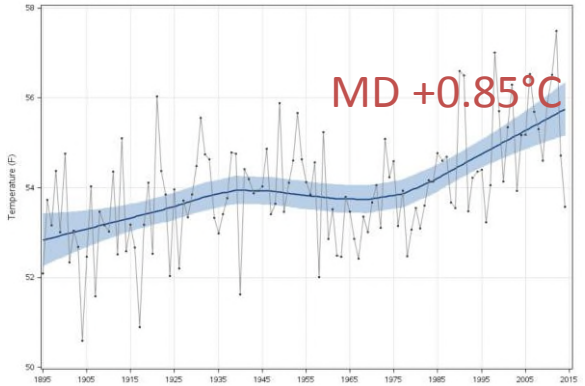
Annual temperature for 1895 to 2015 are shown.

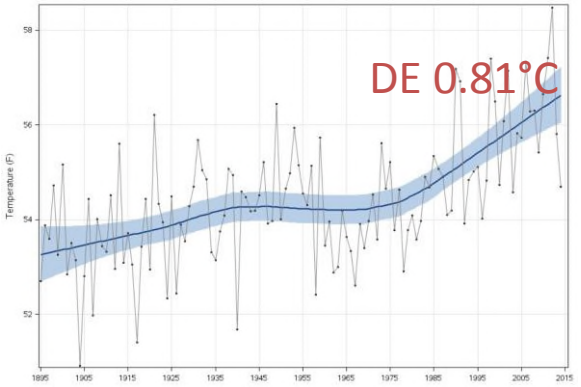
Annual Temperature
Trend Line
95% Confidence Limits

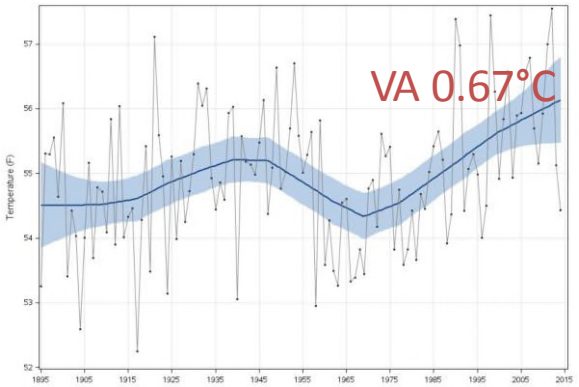












Approx. increases over the last 30 years based on the trend line are shown.

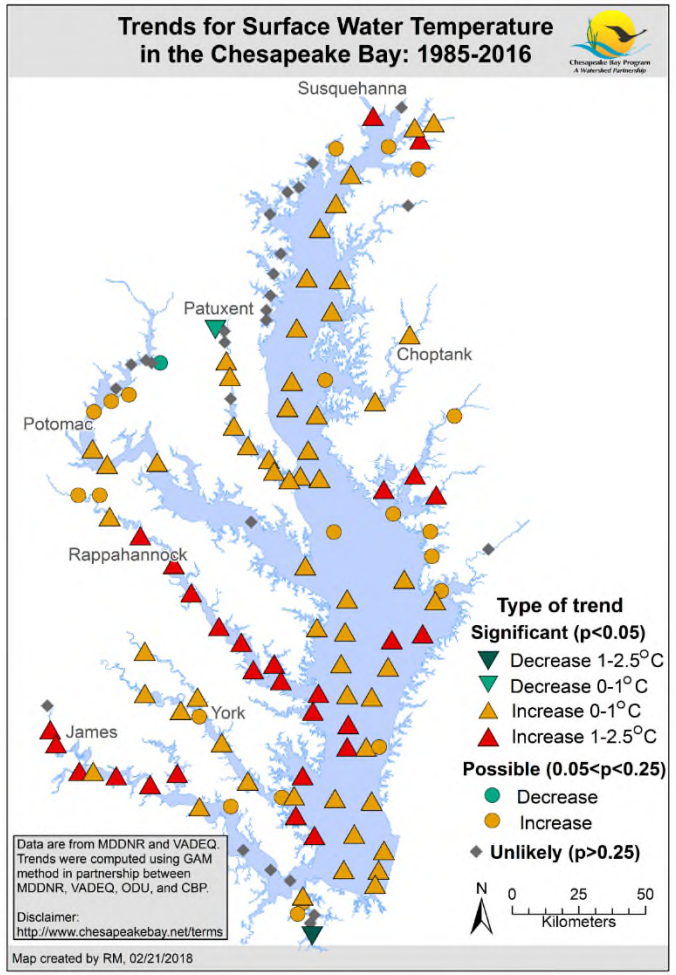
NOAA National Climatic Data Center
https://www.ncdc.noaa.gov/temp-and-precip/state-temps/

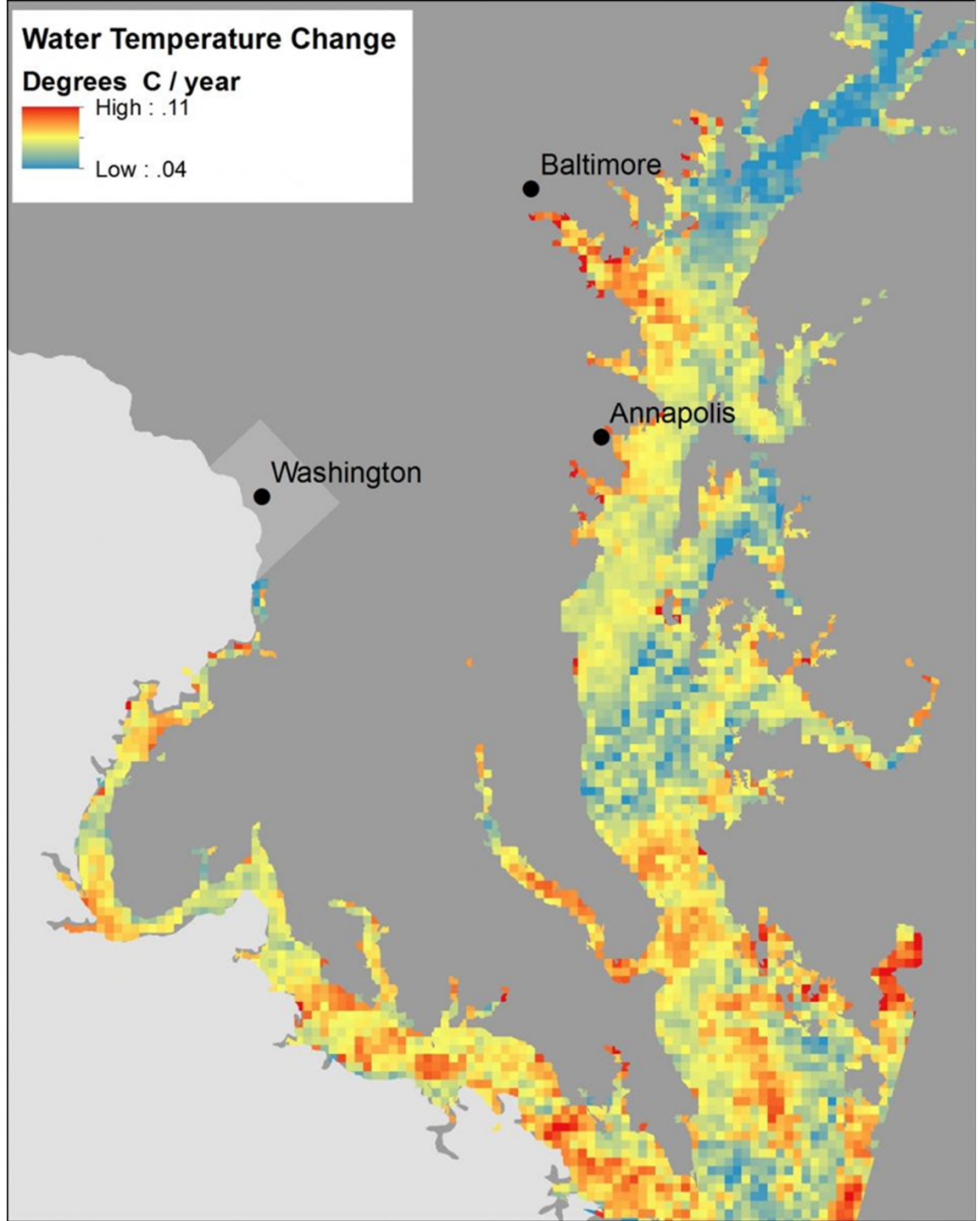
Indicator Development Status at a Glance

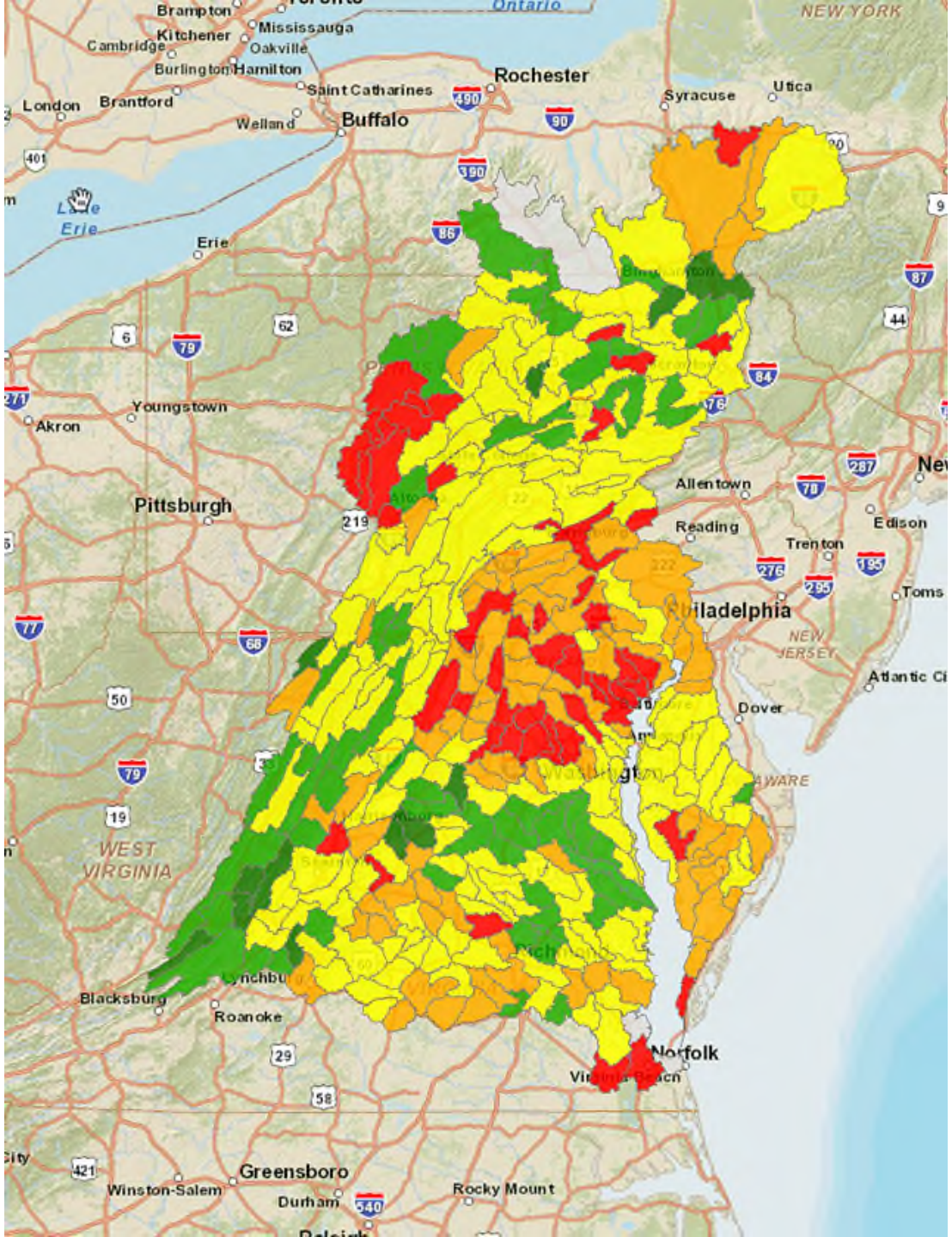
Topic	Type of indicator	Stage 1: Indicator and metric(s) defined	Stage 2: Data collection program in place	Stage 3: Methods selected to transform data into an indicator	Stage 4: Data processed	Stage 5: Indicator developed for the Chesapeake
Group A: Chesapeake indicator already exists						
Protected Lands	Resilience or response	✓	✓	✓	✓	✓
Restored Habitat	Resilience or response	✓	✓	✓	✓	✓
Group B: Existing national indicator just needs to be clipped or cropped						
Air Temperature	Physical stressors	✓	✓	✓	✓	
Coastal Flooding	Impacts	✓	✓	✓	✓	
Precipitation	Physical stressors	✓	✓	✓	✓	
Sea Level Change	Physical stressors	✓	✓	✓	✓	
Stream Water Temperature	Physical stressors	✓	partial	✓	✓	
Upstream Flooding	Impacts	✓	✓	✓	✓	
Group C: Indicator defined, but need to process data and develop indicator						
Acidification	Physical stressors	✓	✓			
Bay Water Temperature	Physical stressors	✓	✓	partial		
Harmful Algal Blooms	Impacts	✓	✓	✓	partial	partial
Property at Risk or Damaged	Impacts	partial	✓			
Urban Tree Canopy	Resilience or response	✓	✓			
Wetland Extent and Physical Buffering Capacity	Impacts	✓	partial	partial		
Group D: Data likely exist, but need to define and develop indicator						
Bird Species Ranges	Impacts		✓			
BMPs and Green Infrastructure	Resilience or response					
Land Use/Land Cover	Resilience or response		✓			
Shoreline Condition	Resilience or response		✓			
Wetland Migration Corridors	Resilience or response		✓			
Group E: Could require a new data collection program						
Fish Population Distribution	Impacts / resilience or response					
Submerged Aquatic Vegetation Composition	Impacts / resilience or response					

Using existing data to propose and develop climate change indicator needs of the partnership.

Advancement: Generalized Additive Model (GAMs) trend approaches have been adopted to explain water quality trends




Water Temperature Change
Degrees C / year
High : .11
Low : .04
Baltimore
Annapolis
Washington



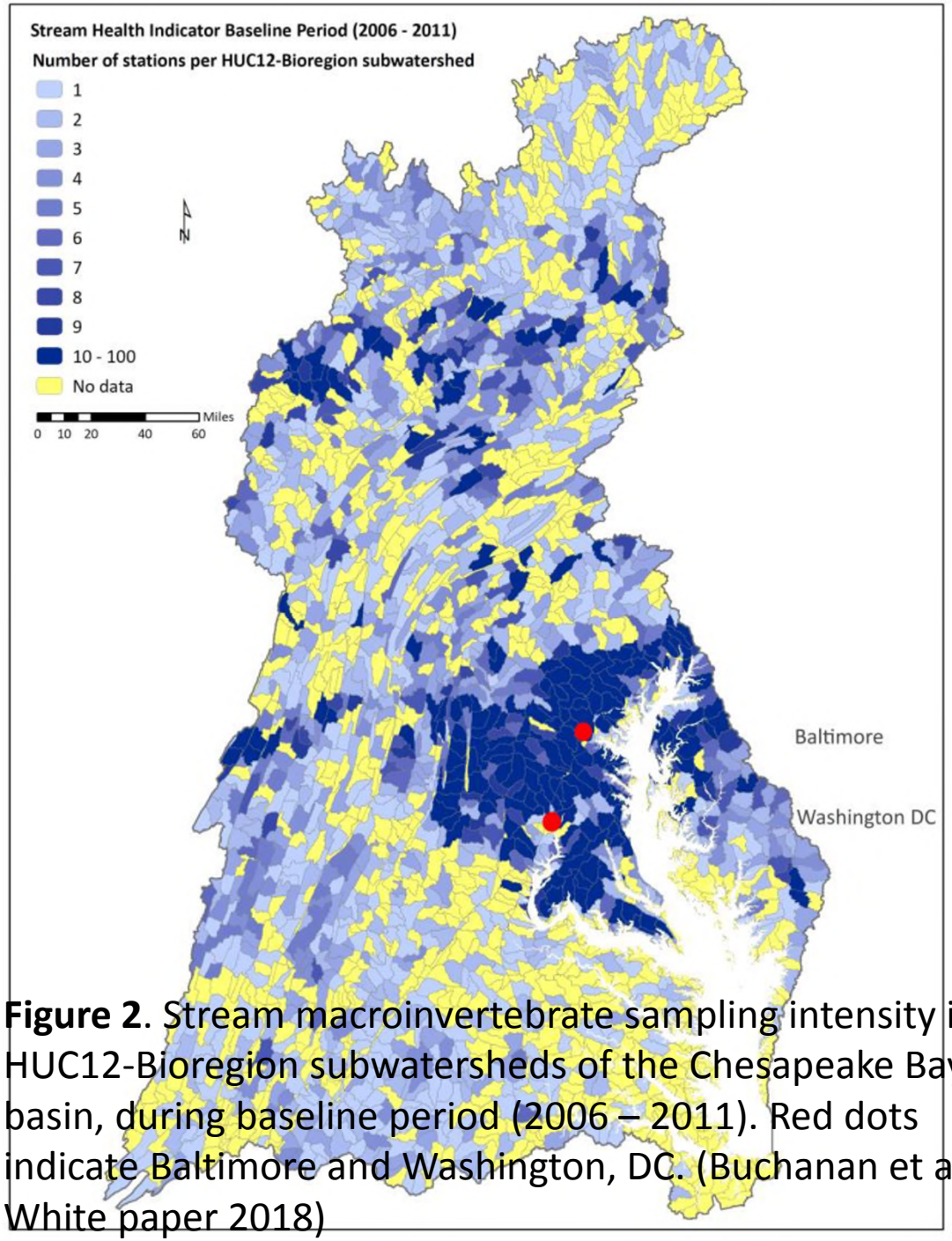
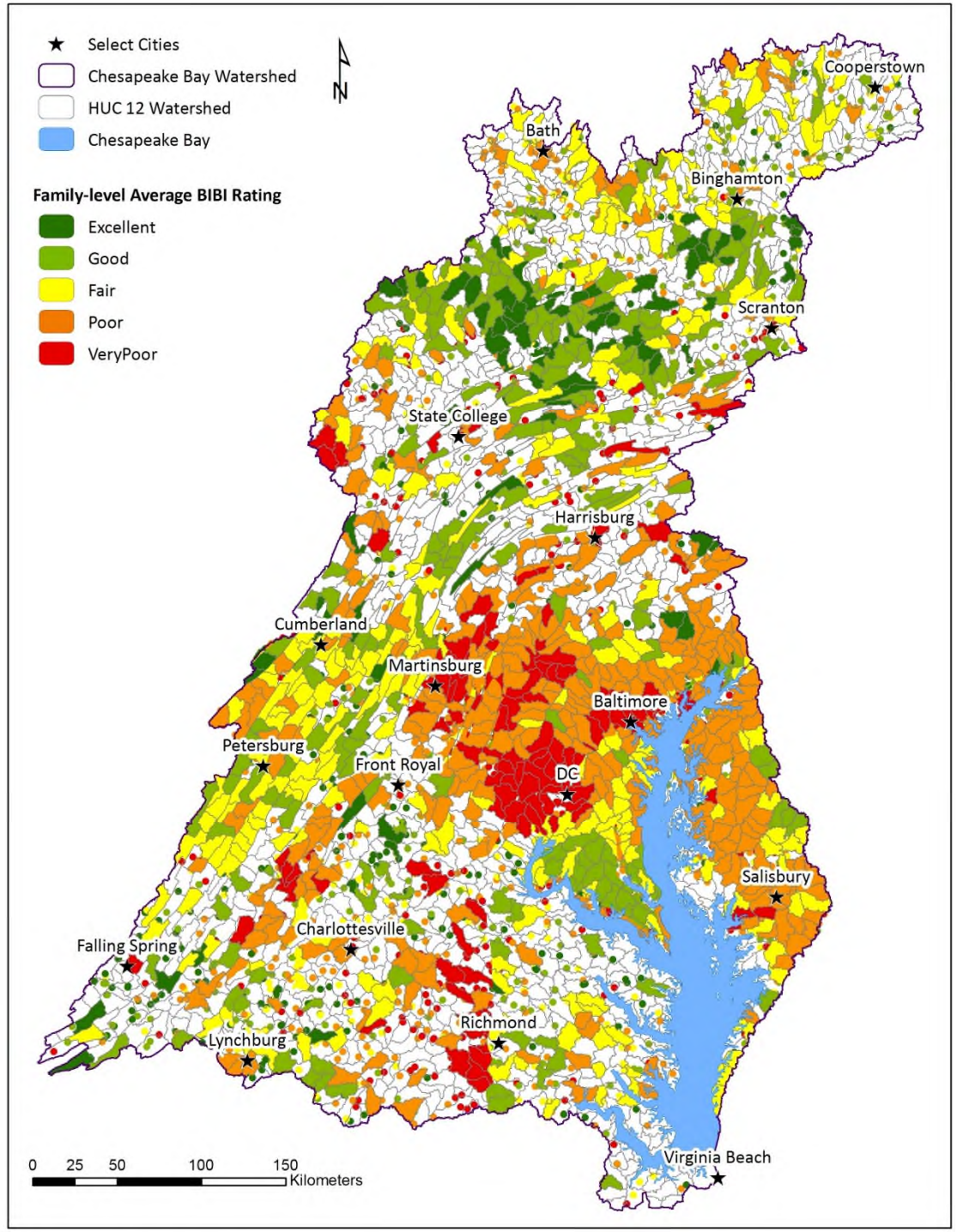


Figure 2. Stream macroinvertebrate sampling intensity in HUC12-Bioregion subwatersheds of the Chesapeake Bay basin, during baseline period (2006 – 2011). Red dots indicate Baltimore and Washington, DC. (Buchanan et al. White paper 2018)


Select Cities
Chesapeake Bay Watershed
HUC 12 Watershed
Chesapeake Bay
Family-level Average BIBI Rating
Excellent
Good
Fair
Poor
VeryPoor
N
Cooperstown
Bath
Binghamton
Scranton
State College
Harrisburg
Cumberland
Martinsburg
Baltimore
Petersburg
Front Royal
DC
Salisbury
Charlottesville
Falling Spring
Richmond
Lynchburg
Virginia Beach
0 25 50 100 150
Kilometers

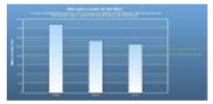
2014 Chesapeake Watershed Agreement Goals and Outcomes

Sustainable Fisheries

- Blue Crab Abundance
- Blue Crab Management
- Oyster
- Forage Fish
- Fish Habitat

Vital Habitats Goal

- Wetlands
- Black Duck
- Stream Health
- Brook Trout
- Fish Passage
- Submerged Aquatic Vegetation (SAV)
- Forest Buffer
- Tree Canopy



Water Quality Goal

- 2017 Watershed Implementation Plans (WIP)
- 2025 WIP
- Water Quality Standards Attainment and Monitoring

Toxic Contaminants Goal

- Toxic Contaminants Research
- Toxic Contaminants Policy and Prevention

Healthy Watersheds Goal

- Healthy Waters

Stewardship Goal

- Citizen Stewardship
- Local Leadership
- Diversity

Land Conservation Goal

- Protected Lands
- Land Use Methods and Metrics Development
- Land Use Options Evaluation

Public Access Goal

- Public Access Site Development

Environmental Literacy Goal

- Student
- Sustainable Schools
- Environmental Literacy Planning

Climate Resiliency Goal

- Monitoring and Assessment
- Adaptation Outcome

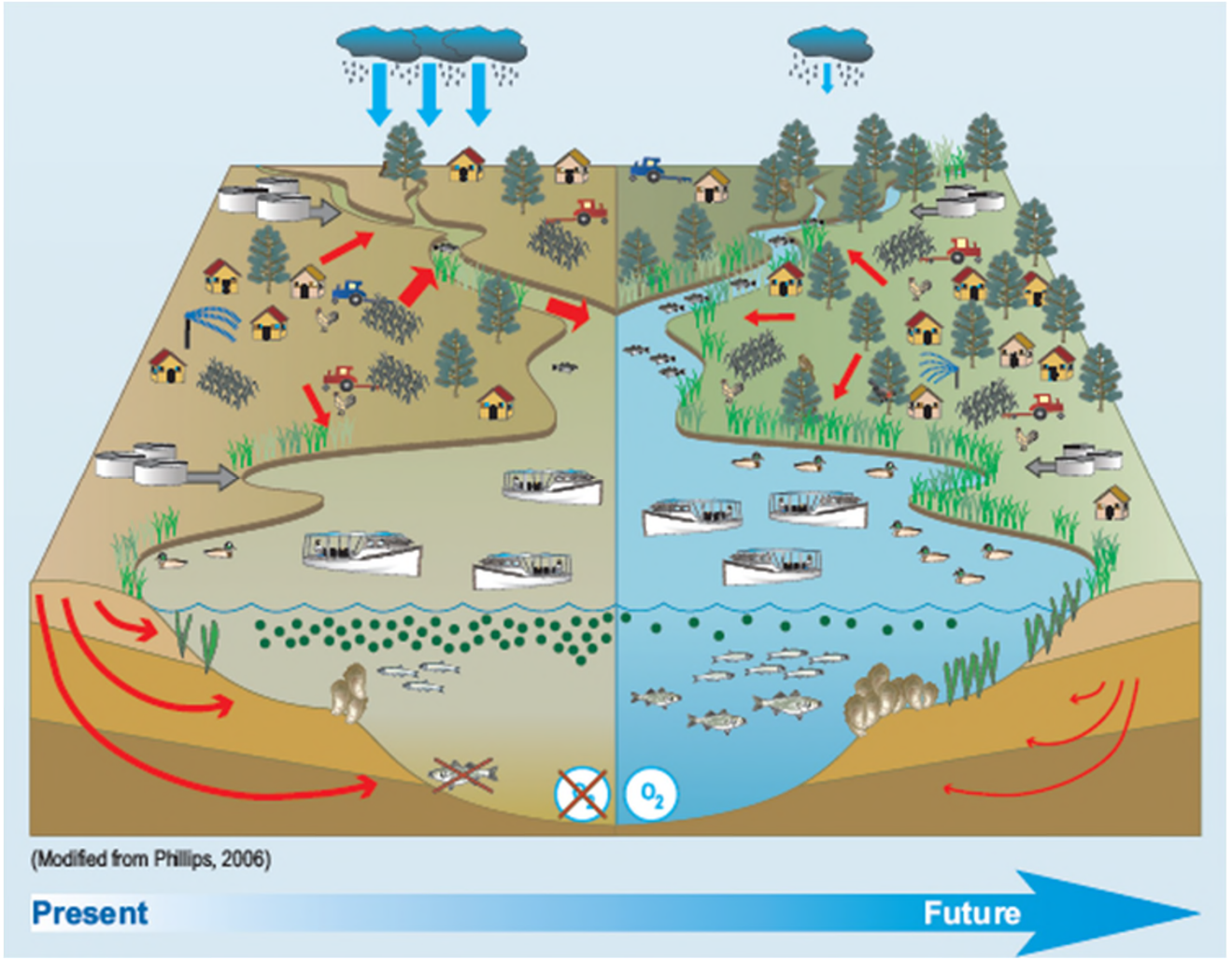
Links with data needs

Data needs:

- Spatial coverage: Local scale assessments to regional scale coverage
- Spatial resolution: desirable = as small as can be provided (e.g. 1m x 1m), however, it really depends on the indicator.

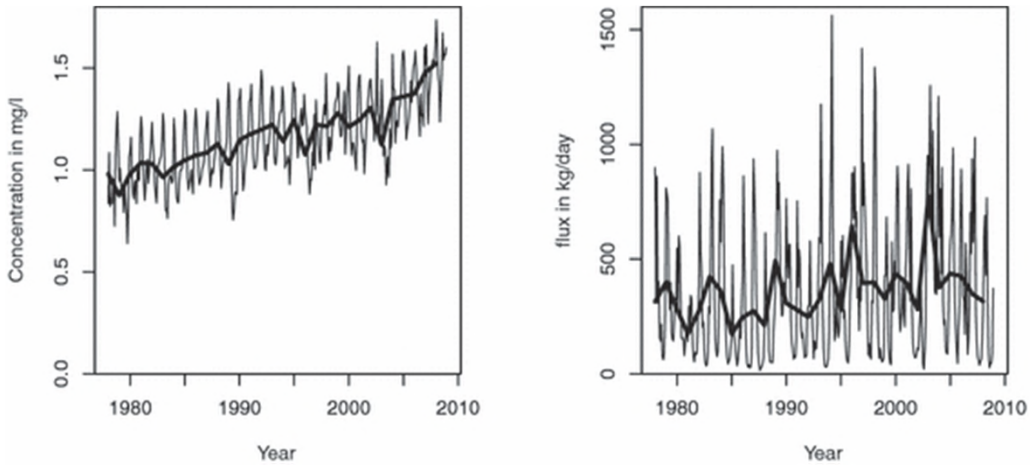
- Temporal coverage: Consistent data collection programming through time with reliable support.
- Temporal resolution: indicator dependent again. Many seasonal to annual scale data interests (needing multiple data points within a season or over the year) but something like harmful algal bloom tracking or flooding could be daily to weekly.

Restored system meets its water quality standards



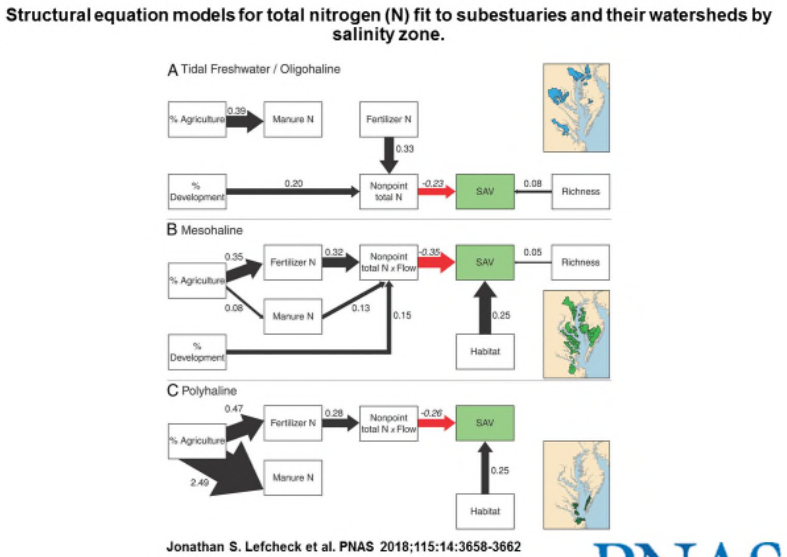
Applicable Water quality Standards
Water clarity/bay grasses
Chlorophyll
Dissolved oxygen

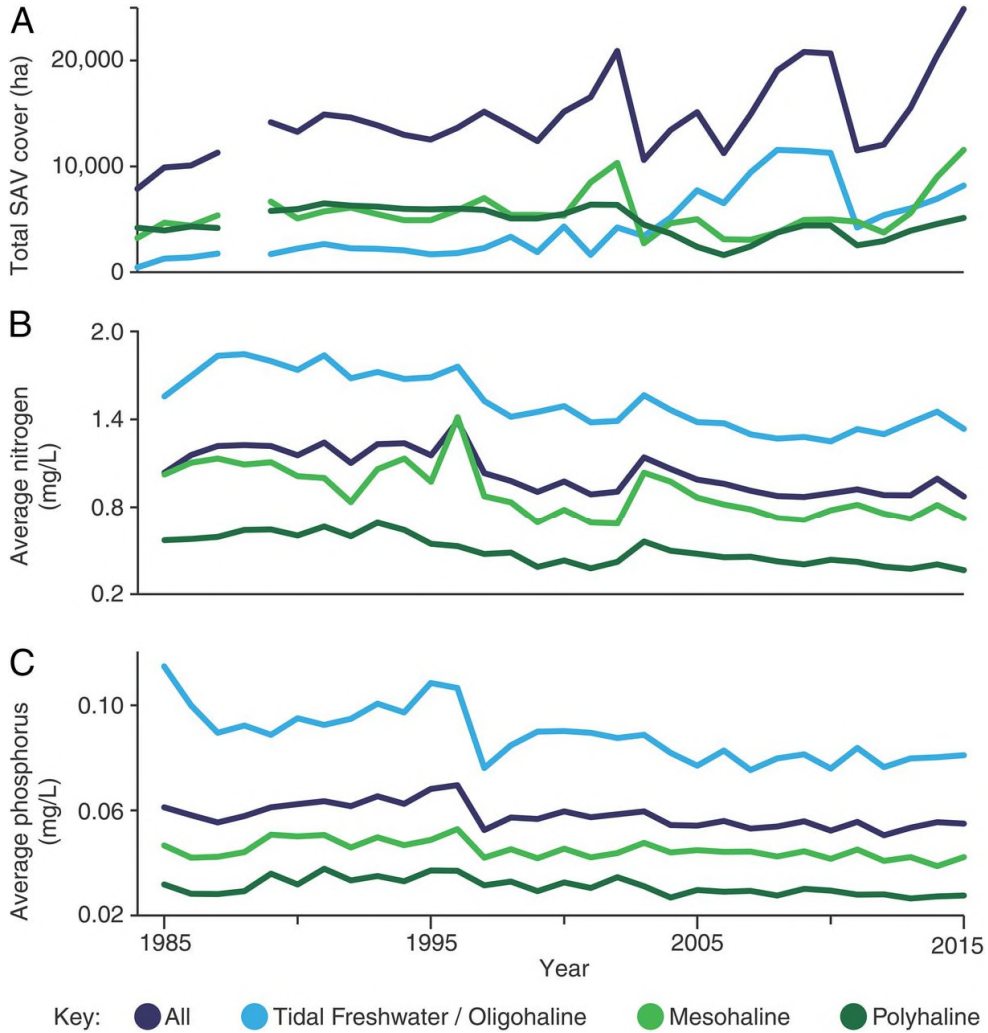
Weighted Regressions on Time, Discharge, and Season (WRTDS), with an Application to Chesapeake Bay River Inputs1



JAWRA Journal of the American Water Resources Association
Volume 46, Issue 5, pages 857-880, 7 SEP 2010 DOI: 10.1111/j.1752-1688.2010.00482.x
http://onlinelibrary.wiley.com/doi/10.1111/j.1752-1688.2010.00482.x/full#f12

Annual bay-wide trends, and trends by salinity zone, in (A) total observed SAV cover (hectares, from aerial monitoring survey), (B) mean water column nitrogen, and (C) mean water column phosphorus concentrations (milligrams per liter, from in situ...





Jonathan S. Lefcheck et al. PNAS 2018;115:14:3658-3662

PNAS